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A MOTOR WITHOUT FUEL AND THE SECOND PRINCIPLE OF THERMO-DYNAMICS.

BY DR. HERMANN MEHNER.

[*Read at the stated meeting of the Institute, December 16, 1891.*]

JOS. M. WILSON, President, in the chair.

DR. MEHNER: Since the time when men began to use motors, thinking and progressive minds have been impressed by the value of the precious service done by mechanical power, and have been seeking to produce such mechanical power.

The histories of the investigators in this field are sad—hard toil, bitter deceptions, meagre successes. Wherever nature showed, or seemed to show, an unutilized force, these eager explorers in mechanical powers exerted their best endeavors, and they were deceived, either because there was no force or because the force was not able to do work or required mechanical work to make it available.

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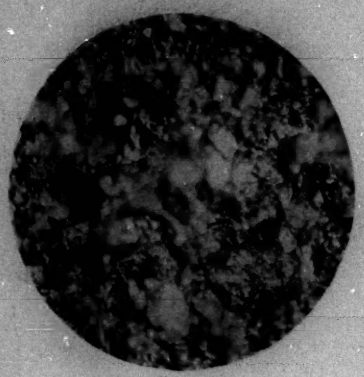
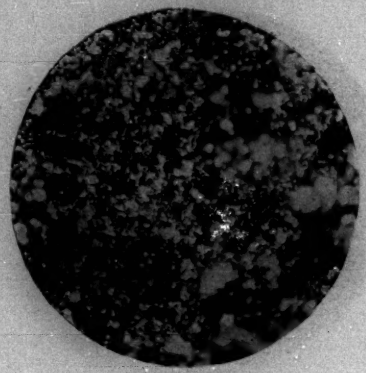


FIG. 1.



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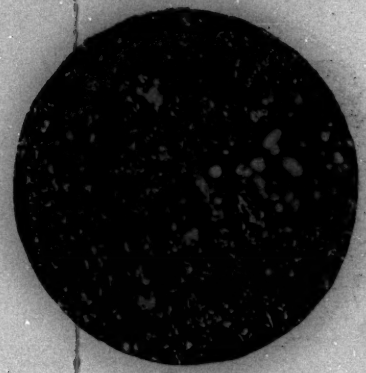


FIG. 3.

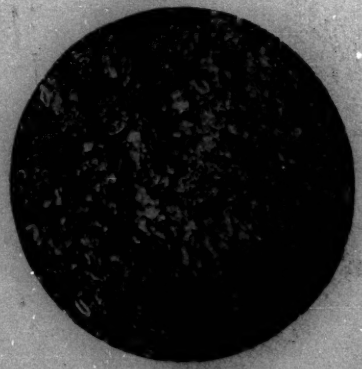


FIG. 4.

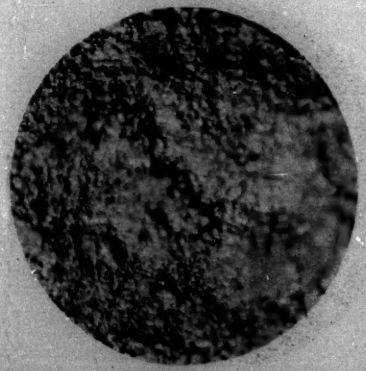


FIG. 5.

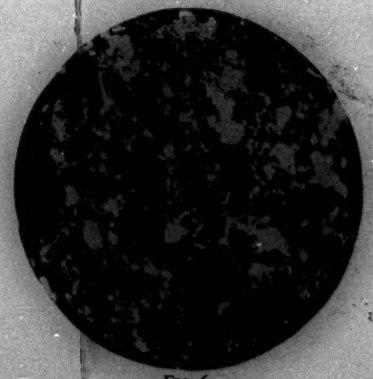


FIG. 6.

STANDARD COMMERCIAL GRADES OF PIG IRON.—(See pages 138–139.)

Of such was the constructor of the *perpetuum mobile*, who, in his imagination, ran a wheel around inside of a hoop by the continuous force of a coiled piece of watch-spring—the philosophical miller who proposed to pump his water back and use it over and over again in his wheel.

These inventors were deceived by natural causes, but others have found their work to be useless because of social conditions. Such was the case with the unhappy genius Papin, who knew a peculiar force, which we call the pressure of the atmosphere; who knew how to produce conditions under which this force was able to do work and thus had in his vessel a wonderful energy capable of moving for a distance of several feet the respectable weight of fifteen pounds for each square inch, and to repeat this as often as he pleased, but he could not sell it.

Social conditions prevented him from developing his device, even to the low level of the Newcomen machine.

We pity Papin, but, to my way of thinking, we owe as much sympathy to the deceived inventor with the watch-spring and the unfortunate miller, the strong-minded men who work hard, much less for their personal interest than with the magnanimous desire to confer a gift valuable to mankind.

For it is much simpler and easier to grind grain and make money, and afterwards to celebrate thanksgiving, than to grind thoughts against thoughts, make sacrifices of pleasure, time and money, and to keep at this after many meagre and bitter thanksgivings.

Mankind owes its thanks to these deceived inventors because especially in the early state of mechanical science the record and the discussion of such unsuccessful explorations increase the chances of those who at length achieve success. As there is no plan, guide or time-table for travellers in the darkest Africa of natural philosophy, there is nothing for the pioneer but to try.

The search for power where there is none, advanced scientific mechanics just as alchemy advanced early chemistry.

If the search for sources of mechanical power brings one

success, the advantage to the commonwealth pays a thousandfold all the loss which futile experiments have inflicted upon it. Watt's fortunate contrivance is not a mere object of property; it is the *foundation* of our present form of commonwealth, technically and socially.

Nowadays steam-power is all: but for the inventor it is nothing.

The very abundance of mechanical power and its application for so many purposes, show how this application is limited and impress the mind that another, better and cheaper power is a necessity.

Many philosophical minds are so impressed; you will see them putting turbine wheels in every accessible waterfall; you see them trying to utilize the gigantic energy of Niagara; you hear of sunshine machines which concentrate the beams by large reflectors; you read speculations about the energy of the tides; you find schemers appreciating again the feeble power of the wind; and so on through the list of nature's wasted forces.

Let us not forget another project as we are in a *Franklin* Institute. There is the flash of lightning, a high tension current of so many million volts. Make it strike a huge transformer and store it up in accumulators. Well, we need a cheaper power!

I began trying to solve this problem while I was yet a student in my first term—but not that of the *perpetuum mobile*.

Students are instructed now carefully. Each inviting by-way which leads astray is marked by a finger-post; the nature of a force is thoroughly explained, using for illustration the 150,000 pounds to the square inch on the bottom of the ocean, and the comparison is made with physical work, like that done by the falling weight of a clock mechanism. They are shown that wherever energy in one form appears, energy in another form disappears. A lighthouse is planted on every cliff of perpetual motion, so that really a student cannot well invent it. As I had before this time read Liebig's popular letters on chemistry, some popular lectures of Helmholtz, and was just engaged in studying Robert

Mayer's book on the *Mechanical Equivalent of Heat*, I was thinking and living so completely in the law of the conservation of energy, that I necessarily took another direction.

My thought was this, quite in line with the practical application of Mayer's discovery:

Mechanical work is an equivalent of consumed heat; why not, by taking the heat away from water, produce a motive-power and leave behind ice?

Such a process would agree perfectly with the accepted law of the conservation of energy.

Of course, I could not find at this time a suitable way to realize the process, and I soon ceased my attempts as I was taught that there is a second law of thermo-dynamics: that the change of the heat form of energy into the form of mechanical work taking place according to the first law, can only be performed if heat can pass from a warmer to a cooler body.

As this law is not so well known by far as that of the conservation of energy, and as it is of the greatest importance in an operative ice machine, which was my aim, I will speak more about it.

The law in the present form is the result of the investigations of Sadi Carnot and Clausius.

The law is explained in the following example of the behavior of a substance in a machine devised in 1824 by Sadi Carnot:

The substance working in the machine has first the temperature of the cooler of the two bodies, which are used in the process, and is in perfect thermal insulation.

Imagine it to be a gas or vapor kept in the cylinder *D* (*Fig. 1*),* with sides, which are perfectly impervious to heat, under a piston of the same quality, but over a bottom, which is a perfect conductor of heat. The cylinder stands on the bench *C*, which is a perfect insulator for heat, so that no heat at all can pass out from it into the cylinder. The substance is now compressed on the bench. Work is spent in this

* This figure is taken from Maxwell's *Theory of Heat*, p. 139.

process and the substance becomes warmer. When it is as warm as the hot body *A* it is placed on that, which is supposed to keep constantly at the higher temperature, no matter how much heat goes out of it. The substance is now allowed to expand, doing work, as, for example, lifting weights. The substance, if insulated, would get cold, but as the body *A* has an unlimited supply of heat which passes through the bottom of ideal conductivity, the temperature of the substance is kept constant. After the substance has expanded, it is replaced on the bench and undergoes the third operation, expanding further in thermal insulation, getting cool by the way and continuing so until the temperature of the substance is that

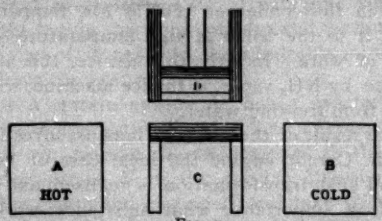


FIG. 1.

of the cold body *B*, which is able to receive an unlimited amount of heat without changing its own temperature. After that, in the fourth operation, the substance is placed on the cold body *B* and compressed, the heat due to the compression being carried away into the cold body *B*.

The compression is continued until the substance has again its original volume, and as far as the substance itself is concerned, the four operations have had no result, the substance being in its initial state. The total result is, that an amount of heat went out from the hot body and an amount of heat went into the cold body. A certain amount of work has been done, and an amount of work has been consumed, the difference in these two quantities of work being the useful work done.

The work done is transformed from heat, and therefore less heat than is taken from *A* is given to *B*.

As an example of an approximate Carnot process, take a steam-boat engine. The substance is water; heat is taken up from the fire gases by the boiler, heat is carried away by the cooling water in the condenser. The condensed water is pumped back by the feed pump.

Such a Carnot engine is reversible in the thermo-dynamic meaning of the word. The working substance can expand in contact with the cooler body; it can then be compressed on the bench till the temperature of the warmer body is reached; it can then in contact with this warmer body be compressed further, etc. This would mean, applied to technics: An engine can pump out cold vapor from the condenser and compress it, forming hot water in the boiler, taking up in the condenser heat at low temperature and delivering it to the boiler at high temperature by the consumption of work. Exactly this device, run at ordinary temperature by NH_3 vapor, is the ice machine, which takes away heat from freezing water.

Now, the result of the Carnot-Clausius investigation is that in the Carnot engine the ideal case of heat transmission and heat transformation is realized, and that it is not at all of importance what substance works in the engine. The efficiency does not depend upon the substance, but only upon the temperatures of the warmer and cooler bodies. If the engine works in this ideal way between 150° and 70° C., it performs exactly the same work, for each unit of heat which it receives, whether it be operated by water, starting with a tension of about 4·7 atmospheres (at fifteen pounds per square inch each), and condensing at one-third atmosphere; or by alcohol, working between 9·6 and 0·7 atmospheres; or by turpentine, the working pressure of which would vary between 1 and 0·08 atmospheres at the stated temperatures; or by carbon-disulphide expanding from 12 to 2 atmospheres; and this engine delivers to the condenser exactly the same amount of heat: and this work is, as mentioned above, the maximum: and this heat is the minimum which any machine *could* deliver, however good it may be. This very interesting statement is the result of the Carnot-Clausius law—not of experience.

This law has been proved by a demonstration which fails to satisfy the student, and it was much doubted in its early days. Helmholtz, for example, in 1854, accepted it in a lecture on the correlation of forces, with a good deal of reservation. But now, all that seems to be forgotten. Many inferences have been drawn from it, and as the inferences, where they can be criticised by experience, agree with the latter; the law stands firmly like the conservation of energy and matter. There is only one, the famous French physicist, Bertrand, who doubts the law, but he stands so isolated that his opinion is generally overlooked. He says, in his *Thermo-dynamique*, Paris, 1887, p. 266: "*Les demonstrations proposées jusqu'ici ne rendent pour moi le théorème ni certain ni vraisemblable.*" I will give you the principle for the law in the words of Maxwell, because if anything like a proof is possible, the admirable mind of Maxwell will have the best one.

Suppose a certain engine M has a greater efficiency between the temperatures S and T than a reversible engine N; then if we connect the two engines so that M by a direct action drives N in the reverse direction, at each stroke of the compound engine N will take from the cold body B, the heat H, and by the expenditure of work W, give to the hot body A, the heat H'.

The engine M will receive this heat H' and by hypothesis will do more work while transferring it to B than is required to drive the engine N.

Hence at every stroke there will be an excess of useful work done by the combined engine.

We must not suppose, however, that this is a violation of the principle of the conservation of energy, for if M does more work than N would do, it converts more heat into work at every stroke, and therefore M restores to the cold body a smaller quantity of heat than N takes from it. Hence the legitimate conclusion from the hypothesis is, that the combined engine will, by its unaided action, convert the heat of the cold body B into mechanical work, and that this process may go on till all heat in the system is converted into useful work.

"This is manifestly contrary to experience, and therefore we must admit that no engine can have an efficiency greater than that of a reversible engine working between the same temperatures."*

Such is the proof of the Carnot-Clausius law in the words of this great physicist, whom I admire. To condense it in an example: If there were a machine *M*, better than the Carnot machine, in a steam-boat, it could be run with the help of a reversed Carnot machine by the heat of the cold sea-water—which is against experience. In other words, no machine better than Carnot's is ever possible, because—there is no such machine!

The proof of Clausius is of a different character. He first generalizes an experience into an axiom:

Heat cannot travel without compensation from a cooler to a warmer body, explaining compensation as expense of mechanical work or irreversible change of any kind in nature.

After assuming this axiom, he causes the reversed Carnot and the supposed better machine, to work with another, as Maxwell does, and easily shows that the result is against the axiom.

I have the impression that Clausius was looking for a more satisfactory cause, for an internal cause in the nature of heat, for the limitation of the efficiency of the Carnot machine: perhaps he wanted natural necessity instead of simple experience, which Maxwell clearly states. But in this way he makes a much broader claim than Maxwell does. Maxwell claims a maximum rate of transformation for a working heat. Clausius also claims that, but claims further, that the remaining untransformed heat can never be elevated again without compensation. It is proper to separate in the investigation these two propositions, as that of Clausius includes or hides the first, while the first does not necessarily compel us to assume the second.

My opinion in regard to the law is as follows:

When I see that the law of Carnot-Clausius is demon-

* From Maxwell's *Theory on Heat*, p. 152.

strated as shown and at the same time consider carefully its applications in thermo-dynamics and chemistry. I conceive the law as a general rule, which admits exceptions, and I believe that such exceptions can be found. I claim to have invented one and believe that the famous law will eventually prove to have been the first dim conception of a deeper truth.

It may happen in this case again, as it has happened with the original Carnot law. Generally, and in most cases, if heat passes from a higher to lower temperature, the same amount of heat is found at the low level. Carnot made valuable discoveries in the presumption that this was the case also if work is performed by the way. He saw the truth in the twilight. Clausius corrected the law and showed to us more of the truth, but his law may need correction yet.

Perhaps we are, in thermo-dynamics, in the situation of the leading chemists of the elder generation and in which many chemists are yet in our own day. $O + H_2$ combine and thus produce much heat. All substances produce heat when entering in combination, and no reaction can take place spontaneously—at least not "without compensation" unless heat is developed by it. Therefore, inventors look in the tables of thermo-chemistry to see from them if a reaction is possible. They do not try it, if no heat is developed by it. *But they are wrong.*

In most cases, it is true, this law holds good; but there were found exceptions to it, and the exceptions became too numerous to call the law even a rule, and, accordingly, while until lately the leading chemists have affirmed that no reaction can take place if the *entropy* does not increase by it, they nowadays teach that this condition is a special application for gases of a general law, which makes reactions dependent upon a thermo-dynamical potential, for example, upon the function ψ of Professor Gibbs.

The present Carnot-Clausius law reminds me exactly of the thermo-chemical law and of the original Carnot law.

The origin of this law, the strange way in which it is proved, and the difference between Maxwell and Clausius,

encouraged me to return to my early task of splitting up cold water into ice and useful mechanical energy.

I had to drop it because, according to this second principle, I could not elevate heat. My idea had been to use the heat for expanding a suitable substance, exactly as in ice machines, in which the heat of the freezing water volatilizes liquid ammonia or carbonic acid. I had, of course, to regain this substance, say liquid carbonic acid, and I had to do that at a lower temperature, because at the same temperature the compression would cost as much work as the expansion could deliver.

But I believed the matter unsettled, not at all on account of the reasoning about the second principle that I have just given—I was not so critical at that time—but because the theory, especially in its consequences concerning the end of the world, was repugnant to my feelings.

After much reflection and study, I think I have finally devised a method which I believe gives the solution of the problem. When I came to study the phenomena of Honigmann's well-known soda engine, I found in a certain class of chemical reactions the means of absorbing the anhydrous ammonia, or the carbonic acid, which had prevented my success.

I found, for example—not in the laboratory, but already as a well-established fact in literature—that many salts of ammonia absorb ammonia gas of a lower tension at a low temperature, that is, below the freezing point; and at a high temperature, that is, at the ordinary temperature of the atmosphere, or that of running water, develop it at a high tension. This was very inviting for further study.

An engine using ammonia should deliver in its exhaust the amount of heat, which any machine will deliver to the cooler body. But there was the advantageous circumstance that most of the ammonia combinations having little NH_3 were solids, and by absorption of NH_3 became liquids —and liquefaction *generally absorbs* heat. The liquefaction of NH_3 salts, as a fact, consumes heat. So, perhaps, the latent heat of liquefaction was equal to the latent heat of condensa-

tion (I prefer to say of absorption) of the NH_3 vapor. If that was the case, a motor without fuel was invented, no matter if it really made ice or only slightly cooled the surroundings.

I did not know the quantity of this heat of liquefaction exactly, but I estimated it by comparing it with similar data, and I came to the conclusion that favorable conditions could be chosen, in which the heat of absorption could be utilized by the opposite heat of liquefaction.

Thus I broke through the principle. Afterwards I made more satisfactory calculations for a motor serving as an example, a motor based on the same principle, but acting at high temperature, and with fairly well-known substances. I refer to the saltpetre machine which I lately described in the *Scientific American Supplement*, December 5, 1891. I think I am permitted to presume that this description is well known to the readers of the *Journal*, so that I have no need to refer to it further. I wish here to treat it chiefly in its bearing upon the second principle.

The question is: Is it true that by the use of a solution, which is formed with absorption of heat, heat can be elevated without expense of mechanical work, without compensation?

Suppose that the latent heat of a vapor (which by present methods must be delivered in the condenser to a cooler body), by the solution of a solid substance is kept latent or bound. Is it not necessary, just because it is bound, to apply in order to liberate it afterwards by evaporation, at least an equal amount of heat from an outside source?

I had this objection presented to me from so respectable a source, that I will here discuss it. You will see that this attempt to defend the second principle of thermo-dynamics must cost the first. It violates the law of conservation of energy. Call the bound heat Q_2, corresponding to a heat Q_1 which must be introduced to the working substance of a Carnot machine at the higher temperature and consists in my motor of $Q_2 + Q_L$, Q_L being the equivalent of the work to be done.

Now after the heat Q_2 is bound in the freezing mixture

and so indissolubly bound that it requires another heat Q_2 to liberate it, and after this second Q_2 *has* liberated it, it must be free. Consequently two amounts Q_2 are ready for work, the first of which might run my motor, and the remaining second might be used again and again to liberate the periodically-bound first Q_2.

But usually the objection has not this meaning. It points to the necessity of spending a second quantity of heat Q_2 for a transformation, for a work which separates the substances combined in the solution; for overcoming the force of affinity.

The objection really means that after the action of the second Q_2, there is only one Q_2.

What became of the first Q_2?

It is not in the solution; the solution exists no more.

It is not in the steam.

This steam is steam; no extraordinary substance. It is quite ordinary steam, which does not show where it came from and behaves exactly like any other steam of the same temperature and pressure made at the expense of the same heat quantity: [second $Q_2 + Q_L$]. You can secretly exchange the steam generated in my way for steam generated in the ordinary way; no physicist can find a difference. Condense my steam and it will set free the second $Q_2 + Q_L$.

The first Q_2 is not in the salt.

The salt is dry—not liquid.

Place this dry salt in the water of condensation and you will find that it cannot dissolve as it can in steam—just because the water of condensation has not this first Q_2, this latent heat which steam has and which the steam once brought to the salt, when it became dissolved in the beginning. The salt cannot dissolve except it can grasp heat from the neighborhood. The salt forms a refrigerating mixture.

It does not help the matter to say that the salt has a high temperature instead of the lower temperature at which it went in solution by the absorption of the first Q_2, and that the difference in the heat contained in the salt when it is desiccated represents Q_2. Take saltpetre and water. No doubt, the salt from the desiccator contains more heat than

the salt which went into the condenser. But the difference is not Q_2. Suppose a machine working with only 10° C. difference of boiler and condenser temperatures. As the latent heat of the salt is about 77 calories, for the condensation of one kilogramme of steam about seven kilogrammes of salt are necessary. After condensing one kilogramme of steam the salt has received about 540 units of heat. This is Q_2. Now cool down the desiccated salt in a calorimeter to the initial state and register the delivered heat. If it is Q_2 it must be 540 calories. Well, that means a specific heat of 540 divided by 10 times 7 = 7·7 for saltpetre. One kilogramme of saltpetre delivers 7·7 units of heat for 1° C. That seems to be pretty high. But now run the motor with only 5° difference in its temperatures. If Q_2 goes into the desiccated salt, the specific heat of saltpetre is 15·4 Take 1° difference and the specific heat necessarily becomes 77. You can bring it to 77,000 calories, if you please, and can vary these interesting results if you will use another solvent instead of water. I take the opportunity to report from the nearest available hand-book, 0·24 (between 0–100° C. from Regnault) as the specific heat of saltpetre.

This shows clearly that the first heat Q_2 cannot remain in the dry salt.

Consequently, the first heat Q_2

is not in the solution;
is not in the steam;
is not in the salt;
is nowhere.

The objection has destroyed it.

I think no objection can survive such an annihilating victory.

It is indeed beyond doubt that a quantity of heat which becomes latent by liquefying a salt at a low temperature, must reappear when the solution becomes solid at a high temperature. *This heat is elevated, if heat is indestructible energy.*

After this deduction it seemed to me superfluous to prove it by an experiment. But I did it when I was invited to do so under very favorable circumstances. I measured

in an electric calorimeter, which I had constructed after the device described in my American patent, the quantity of heat which is necessary to make steam from pure water and the corresponding quantity from concentrated saltpetre solution. The experiment was carried out in Germany in the laboratory of a well-known physicist and specialist in thermo-dynamics. My apparatus was not quite perfect, and gave results that were too high, but this influences the result *against me.*

The heat necessary to form steam from pure water was 621 units; to form it from solution was 334 units.

The difference is far beyond the possibility of any mistake of observation. According to theory I should have found pure water 540 instead of 621, and about 290 instead of 334 for the solution, according to the quantity of saltpetre which was dissolved.

The experiment means this: I really have made the gramme of steam with about one-half the latent heat it contains. Of course, I have not created the other half. This went into the solution before, when the temperature was low and became elevated, as I affirm.

After my views were doubly strengthened in this way, I decided to make every possible effort to secure everywhere the lawful protection for my method to supply the world with power transformed from the ordinary heat of the atmosphere.

I mention here as a detail that I have described, for example in my American patent, a method which makes me independent of the solubility of the salt. It is not necessary that one kilogramme of vapor shall dissolve so much salt that all its latent heat is neutralized. This might be inconvenient or impractical. The vapor may dissolve less and the unneutralized part of the latent heat may be neutralized by another quantity of salt, which dissolves in the liquid solvent, formed at the high temperature.

I will direct your attention to still another feature of my motor by giving an example: The chloride of ammonium, sal-ammoniac, is very soluble in liquid NH_3. It forms a compound, like so many other salts, the compound with three

molecules NH_3, namely, $(NH_4)Cl$, $3NH_3$. This compound decomposes at the ordinary temperature exactly like bicarbonate of soda at a higher temperature, or carbonate of lime at the temperature of the lime kiln. The pressure which is necessary to keep the NH_3 combined with the ammonium chloride is

	mm.
At — 6°	730
+ 6°	1,480
+ 8°	1,800

Now, imagine that you wish to run a machine with NH_3 vapor taken from the decomposing salt at + 6° and combining with it again at — 6°.

The vapor enters the engine with 1,480 mm. pressure, and may expand along the adiabatic line, until it has 730 mm., that is an expansion of only 1 : 2. The temperature, when the absorption pressure is reached, will be about — 36°, but the absorption takes place at — 6°. With the temperature of — 36°, according to Carnot, the heat Q_2 should be taken away or elevated, but with the — 6° it appears. The heat jumps up at once 30° on contact with the salt. If this machine acts with a range of temperature of 42°, the elevation of heat is necessary only through a range of 12°. Other salts show this peculiarity even more strikingly. The neutralizing of the heat at — 6° and its reappearance at + 6°, which happens after the first jump, seems to be very similar to an action of chemical affinity.

From this point of view, that chemical affinity intervenes in my motor, all that is strange in the elevation of heat disappears. There is no heat. The heat is transformed into another form of energy, and is re-transformed into heat at a high temperature, and it cannot surprise us if such other energy does not behave as heat generally does.

I can express the principle of my motor in this way: Carnot's heat Q_2 can only be elevated by another thermodynamical cycle. Thus it costs mechanical work. I substitute for that a thermo-chemical cycle, which costs no mechanical work. My motor in its process perfectly agrees with the theory of Maxwell, in that it transforms as much

heat as the Carnot machine during its action, and it is only after this action is completed that my motor elevates the unused heat against the principle of Clausius, and does this by going outside of the domain of heat.

There is, indeed, nothing unreasonable in the idea of elevating without work, the heat, which in Carnot's cycle is not transformed. If one considers it as an unavailable heat it is very probably simply *called* heat, but is in reality some kind of energy which corresponds at a certain temperature to the quality shown by a substance or which even makes and constitutes this quality. Heat is a collective name applied to such kinds of energy as can raise the temperature of a substance, if they are spent by a first substance. It is remarkable that heat never has been observed. Temperature has been observed, but not the heat which causes it. Even instead of such heat, which we call free in contradistinction from latent, at the very moment of the change from one body to the other, only a quality of a substance has been *observed*. We *presume* and *construct* the heat as a thing behind the phenomenon, like the god Æolus was presumed or constructed behind the change of the winds. Therefore, I often prefer to say energy instead of heat, in order to speak with more exactness.

Now, the so-called heat or energy in the working substance of Carnot consists of two parts Q_2 and Q_L. The energy Q_L is geared into the intrinsic wheel-work of nature in such a way, that sinking down to a lower temperature, it can change into work. The part Q_2 is connected and geared in such a way that going to a lower temperature, it *cannot* change into work. Why should not, therefore, in turning the wheelwork backward, the elevation of the energy Q_L, (which is a *regeneration*) *cost* work, just because of this connection, and the elevation of Q_2 cost *no* work because it moves indifferent to mechanical work?

In my motor, I disconnect the two parts of the energy; I elevate the part which is *unavailable*, and in so doing, I need not spend work, but, in consequence of it, can never do work by it; can never avail myself of this part. Does not that appear reasonable?

Gentlemen, I have explained now the reason which impelled me to go forward with my motor. I have proceeded with full consideration of the laws of nature. I have avoided the slightest attempt to invent perpetual motion according to the first law of thermo-dynamics. I have aimed to obtain mechanical work by simple transformation of heat.

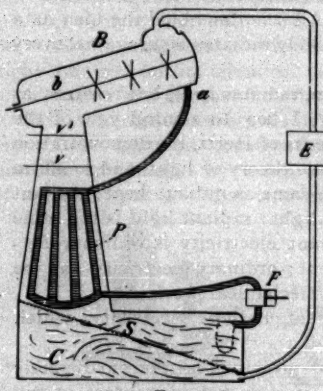


FIG. 2.

EXPLANATION. — The boiler *B* receives a solution at *a* and evaporates it. The solid residue is desiccated and moved forward by help of a suitable stirring device *b*, to the lower end, with the valves V_1 and V_2, which are operated alternately and keep up the separation from the space of low-pressure over and in the condenser *C*. The vapor goes to the engine *E*, and exhausts into the cold lye at *C*. The concentration and low temperature of this lye is kept up by the continuous solution of solid resting on the sieve *S*. The lye is brought back again to the boiler by the feed-pump *F*, passing the pre-heater *P*. This pre-heater is arranged as an example of the possible devices which remove the heat of the warm solid coming from the boiler by contact with the cold lye coming from the condenser; thus bringing the solid to the temperature of the condenser with no loss of heat. (For details, see U. S. Patent, No. 456,831.)

But I take heat of a low temperature. I knew the obstacle of the second principle of thermo-dynamics, but I thought that it might be advisable, under special circumstances, to leave the plain and popular routes of travel, and to try as a solitary explorer a new, untrodden path; and

As this second principle is proved in such an extraordinary manner;

As heat which becomes latent at a low temperature, really reappears at a higher one;

As the latent heat of a vapor makes a wide leap upward by mere contact with an absorbing substance:

As my method, notwithstanding, agrees perfectly with Maxwell's theory and only contradicts the axiom of Clausius; I have resolved that my motor must be built.*

I have lately found another view, which weakens the second principle and brings my method out of its exceptional position. Probably no physicist, Clausius certainly not, makes a distinction between the heat which is in the substances and radiant heat. All scientists hold the idea as a self-evident one, that every body radiates heat against every other body.

A chair, a book in a room, radiates heat, but receives as much by radiation. Now, I beg to remind you of the universally-known experiments of Hertz, the demonstration of Maxwell's electro-magnetic theory of light, and to affirm that: Ordinary heat is the same as radiant heat; radiant heat is the same as radiant light; radiant light is the same as radiant electricity; radiant electricity is ordinary electricity in alternating current; ordinary electricity can be transformed perfectly into mechanical work.

And now another view of radiant electricity, which strengthens the first one.

According to the second principle, no thermo-dynamic machine can produce work if it is not in contact in one part with a warm, and in another part with a cool substance. If the whole machine is surrounded by the same atmosphere with the same temperature everywhere, no action is possible. But I make such a machine run without connecting it with a cooler body. As by radiation everything is connected with everything, the equally tempered surroundings are no obstacle. I take the two reflectors of the old experiment of Mariotte (*Fig. 3*).† In the centre of the one I place instead of the thermometer, the condenser of a little machine, surrounded by warm air like the boiler; in the centre of the other I put a piece of ice. The ice condenses the vapor in the distance, as if the reflector transferred the cold of the ice into the condenser.

* The diagrammatical sketch, *Fig. 2*, shows its appearance in its simplest form.

† From G. M. Hopkins' *Experimental Science*, p. 193.

This experiment, extended to its consequences, seems to show that if there is a cool place anywhere, a warm place equally tempered around a whole machine, can develop mechanical power. It is not necessary to have ice or any cool body connected by radiation with the condenser. Connect the condenser with nothing; have only one reflector and turn it against the endless space of the sky, and the machine runs equally well. On a larger scale, this means the sunshine machine of the hot countries inverted for night-time and for our climates. I might take out a patent for it: a new and improved method of catching cold.

This machine interests us here as a parallel to my motor. It may be constructed as a liquid ammonia machine surrounded by warm air, working with the heat of the atmosphere. That it works can be seen from the

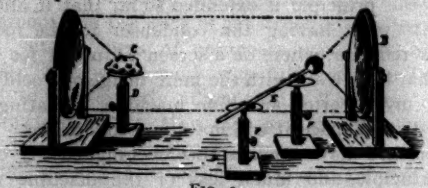


FIG. 3.

fact that a thermometer without any reflector, laid on a box under the free sky, stands lower than another one, near the box if screened from the sky, often by about 20° F. If some one should say that the condenser itself is here Carnot's cooler body, I answer that it is in my machine the same

It seems that the enforced radiation, which might be taken to mean an increased loss from the globe, makes the machine run. But, considered more carefully, it appears that if the condenser enforces radiation, the boiler prevents it. The heat taken by the boiler from the atmosphere leaves so much less to be radiated, and as the condenser radiates less heat than the boiler receives, on account of the mechanical work performed, the radiation from the globe is not increased but diminished. My motor does exactly the same thing. It also takes heat from the store of the globe and prevents it from being radiated away as long as it has

the form of other energies, such as mechanical work, electricity, chemical difference of aluminum and oxygen, and so on. Much more might be said about the parallel between the radiation machine and my motor. I only mention that not even the walls of the condenser are Carnot's cooler body, the working NH_3 itself, in which the condenser has no walls, condenses.

If you will consider this radiation machine working, we will suppose, with the condenser and the boiler in the same air current, you will be compelled to admit either that the second principle is broken down and therefore no longer an obstacle to my method, or that the second principle must be extended until it covers not only the contact, but also the mere distant existence of a cooler space, in which sense it is no longer an obstacle to my motor.

When the principle is extended so far that it allows a machine to work having the condenser in the focus of Mariotte's reflector, where on a screen a lump of ice would appear; that is, to work with the mere image of a cold body, or, as in my inverted sunshine machine, radiating into infinitely distant space, it will not do me any harm.

Gentlemen, I have spoken this evening chiefly of the second principle, and much less of the machine which perhaps equally excites your interest. I did so, because I thought I would better satisfy the members of this scientific institute, if I put aside the mechanical features of the motor, which may change in time, and are very simple ones. I felt obliged to subject to criticism the theory which seems to stand in the way of my thermo-dynamical method.

There has not yet been found a mistake in the processes and details of this method; it has been examined by professional men, friends of mine, by scientists like Prof. Thurston, and, as I am officially notified, by the thermo-dynamical authorities which the American Patent Office consults. Nothing against the processes of the method could be said, except that this general idea, this axiom, which can be applied without hearing more than the *claim* of the method, this dogmatical second principle certainly must kill it, if it is true.

Therefore, I felt impelled to throw some light on this axiom.

THE NICARAGUA CANAL.

By GEO. W. DAVIS,
General Manager Nicaragua Canal Construction Company.

[*A lecture delivered before the Franklin Institute, January 8, 1892.*]

[*Concluded from p. 20.*]

BEGINNING OF WORK OF CONSTRUCTION.

Although some months elapsed after completion of the final surveys before the voluminous plans and detailed drawings were prepared and approved by the Nicaraguan Government, and the work of construction was permitted to begin, yet a corps of engineers was kept constantly employed and when work was initiated, the force only needed to be properly augmented. The first reinforcement was sent out in May, 1889, and others followed from time to time as necessities required. The work itself was not formally inaugurated until the 8th of October of this year, but much valuable preparatory work was done meanwhile, such as the commencement of the erection of permanent quarters, wharves, store-houses, clearing the ground and accumulating supplies, tools, etc.

The necessity of securing a safe entrance to the old harbor (which, until 1860, was easily accessible to vessels of upward of twenty feet draft), was realized as indispensable to economical and rapid progress, and the first work begun of actual construction was in execution of the engineers' plans for restoring the harbor. One of the means to this end was the erection of a breakwater for protection of the entrance. This massive work which will ultimately absorb many hundred thousand cubic yards of the rock excavated from the Divide cut, has been pushed out about 1,000 feet, and is continually being filled in with brush mattresses, rock and hydraulic cement concrete. Quarters for accommodation of the workmen and storage

for supplies were erected near this work. A railroad track was laid upon the breakwater as it advanced, and was extended landward to a point whence was brought the building material and other supplies. In this breakwater, creosoted piling only was used in the frame work, as the marine worm (*teredo navalis*) would soon destroy unprotected wood.

The bar in front of the old San Juan harbor, which, in 1860, was closed by a sand spit formed across its entrance, has since been known as one of the most dangerous on the coast. From the beach to and across this bar the breakwater had to be constructed, and therefore it encountered the full force of the waves, but it has been carried forward through the heavy surf, without stopping at all on account of the weather, and without accident of any kind. As the pier advanced, it afforded a partial shelter to the beach to leeward, and also served as a barrier to the moving beach sand which, impelled by the waves and prevailing winds had formerly been driven constantly to the westward, and so built up and maintained the sand spit that thirty years ago closed the old port San Juan.

This artificial interruption to the operation of the winds and current, which were always active in bringing sand for building and renewal of the beach, permitted countervailing forces of nature to come into play; and the result was that, by the time the pier had been pushed out 600 feet, the sand beach under its lee was swept away and an open channel formed, communicating from the open ocean to the old harbor, now restored to the extent of permitting the entrance of light draft sea-going vessels, and this at a point where six months before was a sand bank three or four feet above the sea level. The attainment of this result was without assistance of a dredge, or any other artificial aid than that afforded by the breakwater. A most important deduction is evident from this experience, namely: That the plan devised by Mr. Menocal for the restoration of the port of San Juan, which some engineers had declared to be impracticable, is sound.

The building of this important work has steadily pro-

gressed as materials were available, and its total length is now 1,000 feet. The outer end is in twenty feet of water, and a force is constantly engaged in filling in the spaces between the piles with mattresses, rock and concrete. The depth of the channel under the lee of the pier reached ten feet when the structure had been extended to 800 feet. In the winter of 1890–91 a dredge increased this depth to about fifteen feet, and this has been maintained since, except in very restricted areas, which are easily deepened by the dredging machines. The first deep sea vessel to enter the restored port was the steamer *Sverdrup*, with a cargo of machinery, etc., on the 7th of January, 1891, and since then many other vessels have frequented the port.

During the summer of 1889 permanent buildings were begun, and building constructions have been in progress ever since. The structures are all of wood (pine from the United States), and roofed with corrugated galvanized iron. The offices, quarters and hospitals are all ceiled and painted inside, have wide verandas outside, and are neat and comfortable. All the permanent buildings so far erected are in the immediate vicinity of San Juan, for at this point is located the general headquarters, and here have been concentrated the most important operations.

The buildings now occupied consist of five groups (all near the sea-beach), and have the floor space stated below:

	Buildings.	*Sq. Ft. Floor.*
Headquarters,	8	13,986
Hospital,	10	14,174
La Fé Depot,	8	21,864
R. R. Headquarters,	9	18,778
Camp Creek,	4	7,100
Total,	39	75,902

Besides the above, there are numerous and extensive wharves, equipped for unloading freight, sheds, small outhouses, water tanks, etc. The machine and smith's shops are equipped with a varied and extensive assortment of modern machine tools, and a tramway connects the more important of these establishments.

The concession allows to the enterprise all the lands

required for any and all purposes incidental to the construction of the whole work, including accessories, and this without charge or cost where lands required belonged to the Government at the date of the concession. In case the lands appropriated by the canal belonged to private owners, compensation is required to be made, the amount to be determined by the usual proceedings of condemnation and expropriation. The 1,000 *manzanas* of land (1,723 acres) have already been placed at the disposal of the company, and payment has been made in the sum of $50,000, as provided in the concession. East of the lake, and all the way to the Atlantic Coast, the whole district is unsettled, save by a few fruit growers, and as the title to the lands still vests in the republic, the cost of expropriations will be merely nominal.

Work in clearing the canal line of forest growth was begun near Greytown in January, 1890, and for a distance of about ten miles back from the coast, the clearing has the full width of 486 feet. The same work was commenced on the west side of Lake Nicaragua in the month of November, 1890, and for nine miles this ground is made ready for the active construction work.

The necessity for a telegraph reaching to the interior, connecting with the telegraph system of the country and the ocean cables, very soon became apparent. This was one of the first works commenced; it was soon pushed through to Castillo, with its loops amounting to sixty miles. The first ten miles of the line back of San Juan was across a very difficult swamp, where the work was most arduous; the poles, which were made of native timber, were difficult of procurement, and together with all other supplies had to be carried by men wading in water from two to four feet deep. The water was so deep that in some places poles could not be set in the earth at all. In such cases they were secured to tree stumps, and otherwise supported by wire guys. Through the hill country the line was also an expensive one to build, and is very difficult to maintain. To ensure immunity from falling timber, a clearing of the forest was necessary 100 feet wide. All the offices and

more important camps and stations are in telephonic communication.

As the heaviest body of work to be accomplished on the whole line is concentrated within a distance of three miles, at what has been designated as the Eastern Divide, and as the time required to complete the canal is measured by the time spent in opening this deep cut, it was felt to be important to install a plant for this heavy rock cutting at the earliest date possible. But so great were the difficulties of transportation of heavy machinery, etc., from the harbor to the site of this heavy cutting, it was at once apparent there was no alternative to be considered but the immediate construction of a railroad. This was begun in the summer of 1890. It extends across what had always been considered an impassable swamp, and for the first ten miles there are but about four miles of hard ground. Soon after beginning heavy rains set in, and the swamp was flooded to a depth of from one to four feet. No earth for filling could be had from along the track, and so all had to come from a distance, brought by train, and these conditions necessitated a reversal of the ordinary proceeding, *i. e.*, laying the track first and making the required embankment afterward.

To accomplish this, novel methods were employed. A heavy corduroy of logs, gotten from the neighboring forest, was laid for many miles. These were rolled, floated or dragged by man-power alone to the line of proposed track, and there arranged as compactly as possible. Upon them were laid longitudinal stringers, also consisting of native tree trunks—the straightest that could be found. Then came the railroad ties, resting on the stringers, and lastly the steel rails, all spiked down. The cars, loaded with sand, were then run out over the log embankment and there unloaded, the sand being packed into the interstices and under the ties, which were raised gradually by the workmen until the desired grade was secured. There were six miles in all of this swamp work. Except in filling the sand trains, no other power was used than that of men, and nearly always the swamp water was above knee deep and

often to the waist or armpits. The material used in grading and ballasting the road-bed was taken from the canal prism, near the harbor, and delivered along the line by trains of cars, loaded by means of a steam shovel or navvy, capable of delivering upon cars 1,300 cubic yards per day.

There are several places along the line, where streams and other water-courses are crossed. These are spanned by pile bridges, and a powerful steam pile driver has been used in their construction. The length of road completed to date is eleven miles—the most difficult of the whole line—and seven miles remain to be completed in order to reach the Divide. There are several miles of side track, switches, etc., already in place.

The road is equipped for construction work, and supplied with four locomotives, fifty cars, steam shovel, ballast unloader, jacks and other requisite appliances. All the cross-ties and bridge timbers are of northern pine, and charged with sixteen pounds creosote oil to the cubic foot. At the railroad terminus on the harbor is a fine wharf, 264 feet long, built in the best manner of creosoted timber, and equipped with modern steam conveniences for handling freight rapidly.

The survey for the remainder of the railroad line, extending to the San Juan River at Ochoa, has been completed; in fact, there have been two lines surveyed and profiles prepared in sufficient detail to enable a close estimation of cost. Between Lake Nicaragua and the Pacific the railroad line is also located, and everything made ready for its construction, which, it is realized, must precede the beginning, upon a large scale, of the work of canal construction itself.

In the summer of 1890 there was purchased from the American Contracting and Dredging Company, the very extensive and valuable plant used so successfully on the eastern end of the Panama Canal from the year 1881 to the collapse of that enterprise in 1888. The property consisted of seven dredges, the most powerful ever built, two fine tug boats, twenty lighters, several launches and a vast quantity of tools, spare parts, materials for repair and renewals,

an entire machine shop, stationary engines, pumps, etc. Many of the articles are in abundance sufficient to suffice until the Nicaragua Canal can be completed. During the autumn of 1890 this property was transferred to San Juan del Norte—all save one of the oldest and least valuable of the dredges, which was lost at sea. Upon the arrival of this plant, portions of it were immediately equipped for work, and three of the dredges have since been in use for various periods—two upon the line of the canal proper and a third in increasing the depth of water at various points in the harbor and upon the bar. The canal line to the width of 280 feet and depth of 17 feet has been opened for 3,000 feet inland from the harbor, the material excavated being sand almost wholly. No buried wood or other obstructions to free dredging have been found. A powerful suction dredge for working upon the bar at San Juan has been constructed in Scotland for this company, and is ready to be sent to its destination.

All the engineers employed on the line have been men of known and tried ability. Those in positions of chief responsibility have had extensive practice in works of engineering construction in the United States and the tropics. All are graduates of the best technical school. Mr. A. G. Menocal, who has been connected with the enterprise from its organization, is the Chief Engineer.

The engineers, administrative staff, surveyors, nearly all the skilled mechanics, foremen, etc., have been hired in the United States and sent out under contract for at least a year's service. The common laborers are of two classes—the natives of Central America and the negroes from the island of Jamaica. All have been housed and fed by the company, and supplied with medicine and hospital attendance free. The rate of wages paid to common laborers varies from twenty to thirty *soles* per month (the Colombian *sole* has a value of about seventy-five cents gold), and it is evident from experience gained that an abundance of acclimated labor, entirely adapted to the company's needs, is readily obtainable from the localities named.

Mention has been made of a steamboat company

operating a line of boats upon the San Juan River and Lake Nicaragua. As the owner of these boats held an exclusive privilege for navigating the San Juan River and Lake Nicaragua by means of steam vessels, it became necessary for this company to acquire the property referred to. This was done in the fall of 1889, and the line has since been operated in the interest of the Construction Company. The franchise is a very valuable one, aside from its bearing upon the construction of the canal.

SUMMARY.

The company has gone to its work of building the canal in a plain, unostentatious, systematic manner, and although nearly all accomplished to date may be described as preliminary, yet a very important advance has been made. These results may be summarized as follows:

(1) The completion of the final surveys for location and construction.

(2) The subterranean examination of the strata requiring removal, by means of borings with the diamond drill.

(3) The restoration of the harbor of San Juan del Norte to the extent of securing an easy entrance to the port for vessels of twelve feet draft.

(4) The construction of extensive wharves and landing facilities.

(5) The erection of permanent buildings for offices, quarters, hospitals, store-houses, shops, etc., having a floor area of an acre and three-fourths.

(6) The building of a large number of temporary camps along the line for accommodation of employés.

(7) The completion of a telegraph line permitting ready communication of the New York office with any part of the work.

(8) The clearing of the canal line of timber for some twenty miles.

(9) The completion of surveys for location and plans of construction of the railroad system, and the construction and equipment of eleven miles of this line.

(10) The acquisition by purchase of the most valuable

and powerful dredging plant to be found in America, under one management.

(11) The fitting up and operation of this plant and the opening of nearly a mile of the canal.

(12) The acquirement by purchase of the valuable and exclusive franchise for the steam navigation of the San Juan River and Lake, together with the extensive plant of the Navigation Company, consisting of offices, lands, steamboats, tugs, lighters, repair shops, etc.

(13) And lastly, what is felt to be the most important result of all is the demonstration, secured by experience, of the salubrity of the climate, the efficiency of labor and the sufficiency of the estimates of the chief engineer for the harbor and canal dredging and railroad work.

Finally, the Government of Nicaragua has formally made acknowledgment of the fact that the company has fully complied with the requirement imposed by the canal grant, which provides that the work of construction shall not be considered as commenced unless $2,000,000 are expended in the first year. This formal acknowledgment confirms the company's title to the concessionary rights for a term of ten years in which to complete the canal and open it for traffic.

FINANCIAL.

The financial questions of inter-oceanic communication across the American Isthmus have been answered, in a very great measure, by the results realized at Suez.

But before considering what has there been demonstrated, an elementary principle of commerce may properly have some attention. Facilities for the transaction of commerce have always induced its development and growth between points at which the primal conditions for its transaction have been found; that is to say, diversity of natural or other resources and a production beyond the requirement of the producer, together with the desirability of its acquisition by the non-producer, as for instance the production of a food supply on the one hand and of manufactured goods on the other, or any other analogous supply and demand.

The operation of this principle has ensured the growth of population, and the extension of empire along the line of water-courses and of oceanic waterways in the past, and in the present time has had one of its most remarkable illustrations in our own country almost within the personal observation of some to whom I am now speaking.

It determined the growth of Chaldea, Assyria and Babylonia along the course of the River Euphrates and of Egypt along the Nile. It made Tyre and Carthage and Venice in turn mistresses of the commerce of the world and mighty political powers, because of their nautical skill and location upon the Mediterranean Sea. It gave the Hanse Towns their despotic power in the Middle Ages, Holland her wealth and Great Britain her prosperity and wide extended empire. England's ships brought to her shores the commodities of foreign climes, some of which she sold at a gain for her services as merchant, but most of which she transmuted by the alchemy of coal and iron and labor, in all of which she was rich, into commodities other and different from what she had received—far beyond her own needs, but needed in other and distant countries with which her fleets gave her the readiest and cheapest communication.

The growth of England's commerce, since the development of steam as a motive-power made her stores of coal and iron the auxiliaries of her commercial enterprise, has been almost beyond belief; in 1839, the aggregate of her imports and exports amounted to £115,281,580; from that time, on the use of steam became more and more general both as a means of transport and as an aid in manufactures. In 1873, when the movement seemed to culminate, the aggregate of England's commerce amounted to £625,128,170. It was the facilities which England afforded for the transaction of commerce, as an ocean carrier and as a converter of raw goods into available fabrics by the use of machinery, which has developed this enormous growth and yielded her its tribute of wealth.

But I have mentioned the illustration of the principle in our own country. In 1826, the first railroad in the State of

New York was built from Albany to Schenectady, a distance of seventeen miles; in 1830, there was still only twenty-three miles of railroad in the United States; in 1832, the total number of miles in operation was but 229. Since then the growth of our railroad system has been rapid, and at the present time we have nearly 170,000 miles of railway, equipped with 30,000 locomotives and 1,000,000 cars, carrying more than 700,000,000 tons of merchandise and 500,000,000 passengers annually.

In 1832, when there was but 229 miles of railway, the population of the country was between 13,000,000 and 14,000,000, mostly distributed along the seaboard, the borders of the Great Lakes and the courses of the great rivers. To-day it amounts to 65,000,000, distributed wherever a railway will carry a man or bring to market the product of his fields or forests or mines. The entire country has reaped the advantage, and growth and prosperity is found not only in narrow strips of country bordering the waterways, but everywhere and over its entire breadth—and not only is the enormous increase and spread of population over inland territory attributable to the facilities afforded for transportation, but the growth of great cities upon the seaboard and even in the interior, to an importance comparable with that of the great cities of Europe, is owing entirely to the facilities the railroads have afforded for interchange of commodities between all parts of our country and between the country at large and the world.

The growth of our foreign commerce, too, is not less remarkable than that of England, and is entitled to as ample provision for its future development. Since 1844, it has grown from $208,350,438 to $1,647,130,043 in 1890, and this year it will exceed $1,800,000,000—a ratio of increase even greater than that of Great Britain during her phenomenal period.

But to return to the demonstration of financial results as indicated by the practical operations of the inter-oceanic canal at Suez.

Statistics show that between seven-eighths and eight-ninths of the actual tonnage passed through that canal

originates at, or is carried to the Atlantic ports of England, Germany, Belgium, the Netherlands, etc., for which the economy of distance traversed does not in any instance exceed 4,400 miles, and in many instances is not more than 1,200 miles.

The saving of distance by the Suez Canal over the Good Hope route between

	Miles.
Liverpool and Bombay is	4,400
Calcutta is	3,681
Hong Kong is	3,331
Yokohama is	3,368
Melbourne is	1,200

Between Liverpool and Auckland, New Zealand, the distance is 1,395 miles less by Nicaragua than by Suez.

For a saving then of 1,200 to 4,400 miles distance in transportation, the commerce of Great Britain, Germany, Holland and Belgium, to the extent of 6,000,000 tons per annum (and the amount is steadily increasing with experience of the advantage), finds it profitable to make use of the Suez Canal, and to pay its tolls.

The Nicaragua Canal offers to the commerce of the eastern ports of the United States, trading to Pacific ports, the advantage of 3,000 to 9,600 miles in distances saved, and to those of Europe from 1,036 to 6,100 miles. The conclusion which these premises warrant is so evident that it seems almost unnecessary to state it. Certainly commerce will avail itself of such an advantage.

But to what extent may it be expected to do so? On this point estimates have differed widely, from as little as 1,901,250 tons to as much as 10,262,494 tons per annum. The smaller estimate was made in 1880 in opposition to the Panama Canal scheme and, as has since become apparent, in the adverse interest of the transatlantic railroads; it was at once shown to be wilfully or ignorantly inadequate and should have no consideration whatever. The next lowest estimate was made in 1890 and amounted to 4,387,000 tons. A careful study of the commerce carried on within the area made more accessible to trade by the Nicaragua Canal, shows that the commerce there existing

amounts in the aggregate to more than 18,000,000 tons per annum, from which total the canal is to derive its share of business and its revenue; with these facts in view I shall not be regarded as unreasonable in claiming that it will have not less than 6,000,000 tons per annum of business as soon as it is open for use; for transit of ocean-going vessels by an inter-oceanic canal is no longer an untried experiment as it was when the Suez Canal was first opened to commerce. Commerce will not now wait to ascertain 'how it works;" that has already been learned, and business men will be ready at once to avail themselves of the advantages proffered.

If the canal tolls be fixed at $2.50 per ton, this amount of traffic (6,000,000 tons) will yield a gross revenue of $15,000,000.

The cost of maintenance and operation of the canal, after the completion, cannot be large. The route is made up principally of broad stretches of water with natural banks, or of cuttings through solid rock which once made will be permanent; and there are no sands drifting from widespread desert plains, as at Suez, to fill its channel continually and make necessary large and unceasing expenses for dredging. The cost of maintenance must, from the nature of things, therefore be moderate. The operation of the lock of the Sault Ste. Marie Canal, which passed nearly 7,500,000 tons in the season of 1890–91, together with all other expenses of that canal for that year, amounted to $45,417. Allowing $50,000 for each of the six locks of the Nicaraguan Canal for operating alone, and making a similarly liberal allowance for maintenance, administration and all other expenses, the total annual cost cannot exceed $1,500,000, which, on an annual traffic of 6,000,000 tons at the rate of toll suggested, shows a net revenue of $13,500,000, or five per cent. on a total capitalization of $270,000,000, to be realized upon the attainment by the enterprise of such a condition of advancement as will afford opportunity for demonstration of its capabilities.

But this estimate of 6,000,000 tons which I have mentioned as the probable tonnage of the canal at its opening,

must not be allowed to limit in your minds its possibilities, or rather its probabilities, which is the more fitting word.

With the opening of the route not only will a new thoroughfare be provided, but new fields will be opened to commerce by the more advantageous provision for its transaction. In this respect the opportunity is unique. The countries chiefly brought into contact by the Suez Canal are old, densely populated and have few new or untried resources awaiting development. On the other hand, western North and South America, Australia, Corea, Japan and eastern Siberia, the abodes of vigorous, rapidly increasing and enterprising peoples, possessing vast resources awaiting development, the magnitude and value of which are already shown to be incalculable by such essays as have been possible under existing conditions, by the canal are brought into closer connection with great commercial centres by a water highway traversing a country unsurpassed in its natural attractions, equally rich in all the material endowments of nature, which, possessed of adequate facilities for travel, must become a resort for travellers from all parts of the world. It would seem that the essential conditions for an unprecedented growth of population, commerce and material prosperity exist here to a degree never before exceeded.

The projected Russian railway, from the heart of that great empire to the port of Vladivostok on the Sea of Japan, will bring into close commercial relations with the United States, all of Asiatic Russia and much of the interior of Central Asia now practically inaccessible to foreign commerce. The lower valley of the Amur, before that river turns northward to its *debouchement* into the sea of Ochotsk, possesses an excellent climate and an exceptionally fertile soil; the same may be said of the soil and climate of extensive areas about the headwaters of other great Siberian rivers further east, flowing to the Arctic Ocean, and many of the richest mines in the world are found in the neighboring mountains, but by reason of remoteness and inaccessibility these resources have been but imperfectly developed. An

enormous expansion of the trade of this region is certain to follow the provision of adequate means of communication, and this development will be vastly stimulated by the opening of an isthmian thoroughfare.

Corea now has a population of 10,000,000, and her trade may be expected to assume important proportions. In 1884, the total value of her exports and imports was but $1,500,000. In 1889, it had risen to over $4,500,000, an increase of more than 227 per cent.

The commerce of Japan, although already of a considerable magnitude, it is to be remembered, is as yet in its infancy, and therefore susceptible of development in a ratio more than normal. As a fact, the commerce of that empire has doubled in the last five years, and its manufacturers are now commencing to buy our cotton for their looms. Japan has a population of 40,000,000, and its people are intelligent, enterprising and progressive. In 1889, its commerce amounted to about $136,000,000, or say $3.40 per capita. The commerce of the United States amounts to over $25 per capita.

The most healthy and most attractive portions of the Spanish-American republics are those bordering on the Pacific Ocean, occupying the western slopes of the mountain chain which traverses the continents. This entire section of country will be brought by the canal nearer to its present markets (which are chiefly in Europe), say from 2,000 to 6,000 miles; but what is of greater importance, it will also be brought from 5,000 to 10,000 miles nearer to New York than at present, and at the same time 2,700 miles, or substantially the width of the Atlantic, nearer to New York than to any European port. Such an advantage cannot fail to have the effect of developing enormously the commerce between these countries and the United States, which at present is but limited.

By the facilities thus afforded for the transactions of commerce, the industries of the several countries will be stimulated and developed, and immigration with its beneficial effects to South American shores as well as to those of California, Oregon, Washington and Alaska will follow. A

great increase of population along the entire western coast of the American continents, together with the growth of commerce which will naturally accompany it, will unquestionably result from the completion of the canal; what it will actually amount to may perhaps be indicated by the example already cited of the development of the United States through the extension of her railroad system. At the same time the markets of the western shores of America will be opened to a coastwise trade with our Atlantic ports; what its aggregate will be is suggested by the fact that such a trade already exists with the West Indies to the extent of 500,000 tons per annum.

In whatever direction attention is turned, the substantial elements are apparent of an enormous and unprecedented commercial development, in connection with the opening of the Nicaragua Canal, such as makes an estimate of results based thereon seem fabulous, and for that reason to be avoided. Enough has been shown to prove that the canal will have an abundant business, from the day when a vessel may pass through it from ocean to ocean, to pay interest on all of the capital ventured in its construction, and to richly reward its projectors.

NATIONAL CONSIDERATIONS.

It is appropriate that your attention be also invited to some of the national aspects of this enterprise.

Ex-President Grant, writing for the *North American Review*, for February, 1881, expressed his convictions as follows:

"In accordance with the early and later policy of the Government, in obedience to the often-expressed will of the American people, with a due regard to our national dignity and power, with a watchful care for the safety and prosperity of our interests and industries on this continent, and with a determination to guard against even the first approach of rival powers, whether friendly or hostile, on these shores, I commend an American canal, on American soil, to the American people and congratulate myself on the fact that the most careful explorations have been started,

TABLE OF DISTANCES, IN NAUTICAL MILES, BETWEEN COMMERCIAL PORTS OF THE WORLD, AND DISTANCES SAVED BY THE NICARAGUA CANAL.

Compiled from Data furnished by the United States Hydrographic Office. Length of Sailing Routes, Approximate Only.

Between	Around Cape Horn for Sailing Vessels.	Via Magellan for Full Powered Steam Vessels.	Via Cape of Good Hope.	Via Nicaragua Canal.	Advantage over Sailing Route.	Advantage over Steam Route.
New York and San Francisco,	15,660	13,174	—	4,907	10,753	8,267
Puget Sound,	—	13,935	—	5,665	—	8,270
Sitka,	—	14,439	—	6,177	—	8,262
Bering Straits,	—	15,705	—	7,402	—	8,303
Acapulco,	—	11,555	—	3,045	—	8,510
Mazatlan,	—	12,037	—	3,675	—	8,362
Hong Kong,	—	—	13,750	10,692	3,058	—
Yokohama,	—	—	15,217	9,257	5,960	—
Melbourne,	13,760	12,860	12,830	9 862	3,898	2,998
Auckland, N. Z.,	12,600	11,599	14,009	8,462	4,138	3,137
Honolulu, S. I.,	15,480	13,290	—	6,417	7,063	6,873
Callao,	—	9 640	—	3,744	—	5,896
Guayaquil,	—	10,300	—	3,227	—	7,073
Valparaiso,	9,420	8,440	—	5,014	4,406	3,426

Between	Around Cape Horn for Sailing Vessels.	Via Magellan for Full Powered Steam Vessels.	Via Cape of Good Hope.	Via Nicaragua Canal.	Advantage over Sailing Route.	Advantage over Steam Route.
New Orleans and San Francisco,	16,000	13,539	—	4,147	11,853	9,392
Acapulco,	—	11,920	—	2,985	—	8,935
Mazatlan,	—	12,402	—	2,915	—	9,487
Callao,	—	10,005	—	2,984	—	7,021
Valparaiso	—	8,805	—	4,254	—	4,551
Liverpool and San Francisco,	15,620	13,494	—	7,627	7,993	5,867
Acapulco,	—	11,875	—	5,765	—	6,110
Mazatlan,	—	12,357	—	6,395	—	5,961
Auckland,	12,130	11,919	13,357	11,182	948	737
Guayaquil,	—	10,620	—	5,947	—	4,673
Callao,	—	9,960	—	6,464	—	3,496
Valparaiso,	9,380	8,760	—	7,734	1,646	1,026
Honolulu,	—	13,610	—	9,137	—	4,473
Yokohama,	—	—	14,505	11,947	—	2,558

Length of Canal (in nautical miles),	147
New York to Eastern Port of Canal,	2,060
Liverpool,	4,780
Hamburg,	5,127
Havre,	4,691
New Orleans,	1,300

Western Port of Canal to San Francisco,	2,700
Portland,	3,345
Puget Sound,	3,458
Valparaiso,	2,807
Callao,	1,537
Yokohama,	7,079

and that the route standing in this attitude before the world, is the one which commends itself as a judicious, economical and prosperous work."

In this connection, the remark of President Hayes, made in his message of March 8, 1880, is pertinent:

"An inter-oceanic canal across the American Isthmus will essentially change the geographical relations between the Atlantic and Pacific Coasts of the United States, and between the United States and the rest of the world. It will be the great ocean thoroughfare between the Atlantic and Pacific shores and virtually a part of the coast line of the United States. Our mere commercial interest in it is greater than that of all other countries, while its relation to our power and our prosperity as a nation, to our means of defence, our unity, peace and safety are matters of paramount importance to the people of the United States."

In a message to the Senate of December 10, 1884, President Arthur transmitted a treaty he had caused to be negotiated with Nicaragua, providing for the assumption by the United States of a permanent protectorate over that country, and for the building, at public expense by our Government, of the Nicaragua Canal. In respect of the work itself and its importance to our country, President Arthur said:

"The establishment of water communication between the Atlantic and Pacific Coasts of the Union is a necessity, the accomplishment of which, however, within the territory of the United States is a physical impossibility. While the enterprise of our citizens has responded to the duty of creating means of speedy transit by rail between the two oceans, these great achievements are inadequate to supply a most important requisite of national union and prosperity. For all maritime purposes the States upon the Pacific are more distant from those upon the Atlantic than if separated by either ocean alone. Europe and Africa are nearer to New York, and Asia is nearer to California than are New York and California to each other by sea. Weeks of steam voyage, or months under sail, are consumed in the passage around the Horn, with the disad-

vantage of traversing tempestuous waters or risking the navigation of the Straits of Magellan. A nation like ours cannot rest satisfied with such a separation of its mutually dependent members. We possess an ocean border of considerably over 10,000 miles on the Atlantic and Gulf of Mexico, and including Alaska, of some 10,000 miles on the Pacific. Within a generation the western coast has developed into an empire with a large and rapidly growing population, with vast but partially developed resources. At the present rate of increase, the end of the century will see us a commonwealth of, perhaps, nearly 100,000,000 inhabitants, of which the West should have a considerably larger and richer proportion than now.

"The political effect of the canal will be to unite closer the States now depending upon railway corporations for all commercial and personal intercourse, and it will not only cheapen the cost of transportation, but will free individuals from the possibility of unjust discriminations."

President Harrison, in his annual message to the Fifty-second Congress, used the following language, which should command the attention of all patriotic citizens of whatever political party:

"I deem it to be a matter of the highest concern to the United States that this canal, connecting the waters of the Atlantic and Pacific Oceans, and giving to us a short water communication between our ports upon those two great seas, should be speedily constructed and at the smallest practicable limit of cost. * * *

"The Senator from Alabama (Mr. Morgan), in his argument upon this subject before the Senate at the last session, did not overestimate the importance of this work when he said that 'the canal is the most important subject now connected with the commercial growth and progress of the United States.' * * *

"I most sincerely hope that neither party nor sectional lines will be drawn upon this great American project, so full of interest to the people of all our States and so influential in its effects upon the prestige and prosperity of our common country."

These are not merely the expressed but the recorded opinions of four of the later Presidents of the United States on a question that has no partisan aspects whatever, and I think we are justified in the belief that the views of the Chief Executive officers of our country reflect the convictions of very large masses of our population.

A Senator, not in political sympathy with the present administration, remarked recently in my presence that he regarded as a great national misfortune the failure of ratification of the Frelinghuysen-Zavala treaty, which it will be remembered had been negotiated during President Arthur's administration.

Thinking men everywhere, regardless of party and section, see plainly the pressing need of convenient means of communication for ships between the oceans washing our shores.

But it is not alone the commercial importance of this work to our country that commends it to the attention of our people. The strategic importance of it has recently been manifested to us.

The strict constructionist of our Constitution finds difficulties in harmonizing the provisions of our Magna Charta with the doctrine of ex-territorial expenditures of the peoples' money, even when a question of national power and defence is involved. The counsel of Washington comes always to mind—that we avoid foreign complications and entangling alliances. But by degrees our people are realizing that our fortunate position, remote from the scenes of strife and contention in the old world, does not exempt us from the rivalries and irritation that often result from commercial intercourse, and efforts to gain new foreign markets and displace the commodities of our rivals in such markets. Great Britain, France, Germany and other manufacturing nations of Europe will not surrender to us willingly their trade in manufactured goods to Japan, China, the East Indies and South America. It is true that for many years we have been unable to actively compete for this trade, but we are making inroads upon it and our manufacturers will soon be in a position to offer such inducements to foreign

buyers as to attract large portions of their traffic to us. The competition resulting will be almost ferocious in character, and happy shall we be if the issue is reached without a trial of military strength.

At present we could neither defend our coasts nor police the oceans effectively. Our enormous wealth, vast portions of it within reach of an enemy's guns, we would be powerless to protect. The conviction by our people of our impotency to preserve our heritage and to protect our citizens abroad, has prompted us to begin the construction of a modern navy and to provide efficient protection for our harbors and foreign commerce. Of our coasts, including Alaska there are 20,000 miles, nearly equally divided between the Atlantic and Pacific, but the length of voyage between our most southern Atlantic port and our most southern Pacific harbor is now more than one-half the circumference of the globe; it is within our power, however, to shorten this to 3,500 miles.

Imagine the military situation under existing conditions in the event of war with any one of the great maritime powers, and let us suppose that all vessels now building and authorized are completed, and the equal in their class of any other navy. In ships and guns we would not possess in the aggregate a number exceeding those assailing us in any one of the three or four fleets that could be mustered by some of the great naval powers of Europe, and our dispositions would of necessity be made for defence only. The enemy would have a fleet on the coast of Japan or China, another near the Cape of Good Hope, and a third near Gibraltar or the Western Islands. Should we wish to transfer any of our vessels from east to west or *vice versa*—a voyage of 12,519 miles is required via the Straits of Magellan between San Diego and Key West. Before our vessels could reach the equator the enemy from Gibraltar could intercept us at Cape St. Roque and the force from Good Hope would be awaiting us at the Straits; or before an American squadron could reach San Diego the hostile ships from China would have anticipated us. How different would be the military situation if we possessed an

isthmian passage, properly fortified, as it would have been under the Frelinghuysen-Zavala treaty!

We are now in the midst of an international controversy of great gravity with one of the nations of South America. The situation is critical in the extreme, and the columns of our daily papers are filled with accounts of hurried naval preparations looking to the enforcement of our demands for reparation. While our force available might be adequate to the execution of the national will, the ships in the Atlantic Ocean can only reach the coast of Chile by way of the Straits of Magellan, and this involves a voyage 3,426 miles longer than would be required if the canal were open and available now. Besides, our country does not possess a coaling station anywhere on or near the existing route, therefore coal for steaming and all other supplies for a fleet operating in the region referred to would have to be forwarded from our own ports. Were the canal open, our depot, in fact, our naval and military base, would be in Nicaragua, but 2,800 miles from the scene of possible conflict, instead of 8,440 miles, as it is now from New York, and about 5,120 miles from San Francisco.

In the great interior lake on the canal line—a body of water one-third as extensive as Lake Erie—would be a marine establishment whence our vessels could dash out upon either ocean and engage the enemy. One "lake" squadron uniting with another from the Gulf of Mexico, could encounter an enemy's fleet among the Caribbees, and returning to the lake to refit could form a junction with our California vessels off the Mexican coast and there contend for mastery with its opponent, all within two weeks of our first action.

The Secretary of the Navy very happily gave expression to the strategic value of an isthmian channel, when he said that the control of such a passage doubled our power for offence and defence, for every one of our ships and guns would be as effective as two of the enemy's.

I cannot detain you with further illustrations, but feel I may venture a single quotation bearing upon this national aspect of the question.

The writer is Captain H. C. Taylor, of our Navy, who certainly has done as much as any other man in bringing this work to public attention: "It is the lake that gives to this route a political and international importance unique and significant. The nation that controls this canal under terms of amity with Nicaragua will here find rest and refreshment for its fleets. Here may the delays of warlike complications, so injurious in sea-water to the iron-hulled frigates of our time, so fatal to their speed, be safely endured without loss of efficiency; the crews growing healthier, the ships more clean-limbed and speedier, in this great fresh water sea. Hence may issue squadrons in the height of vigor and discipline, striking rapid and effective blows in both oceans, and returning to refit in this sheltered stronghold, and to draw from it nourishment and fresh strength for a renewal of hostilities. There cannot be imagined a more potent factor in deciding threatened difficulties or in securing an honorable peace with a powerful enemy, than the presence in this healthy and capacious water fortress of a strong fleet, prepared, at a telegraphic sign from the home government, to issue fully equipped from either entrance for instant service in the Atlantic or Pacific. So vast would be the power of the nation that controlled this transit, and so strong the international jealousies thus created, that it may be considered fortunate that this enterprise should now be moving forward as a purely commercial project, independent of the aid of any government."

NOTES ON THE BLAST FURNACE.

By John Hartman.

[*A lecture delivered before the Franklin Institute, February 19, 1892.*]

Mr. Hartman spoke as follows:

Pig Iron.—History tells that about 1,500 to 1,600 years before Christ the Phœnicians taught the Greeks the manufacture and use of iron. After that time Greek history gives some detailed account of it. The Phœnicians, before leaving their original home on the Indian Ocean, practised the art of iron-making, and on migrating to the Land of Canaan, whose hills were well covered with wood and contained iron ore, they made iron and sold it to the neighboring nations.

Tracing its early history back, it is lost in the twilight of fable. The hurling of Hephæstus from Olympia and the working of iron established by that act, when divested of its fiction, will be found to be the falling of an iron meteorite and the use made of it.

The Cretans' claim to the discovery of iron-making is more rational. Mount Ida in Crete was well wooded and had a fine vein of iron ore on its side. Timber left to grow, decay and fall will accumulate to quite a depth. This timber being accidentally fired at the bottom of the mountain by the inhabitants, in burning upwards burns slower, as the smoke and carbonic acid from below prevents the air from getting freely at the fire above to support combustion. This slow combustion favors turning the wood into charcoal, which, covering any pieces of iron ore, they are reduced or deoxidized by contact with solid carbon. As the wood below is burned off, the pure air sweeping up the hot mountain side, is heated by the ground and rocks, and the charcoal over the ore is burned off at a high heat, causing the slag to flow from the reduced iron, leaving the iron remain as a sponge, which is easily hammered into wrought iron. We have here in nature's work the hot blast and the principle of regenerative furnaces.

The Phœnicians, however, being the older nation, must have the honor of first discovery, and to them more than any other nation the world is indebted for metallurgical science and massive structures. How these people could transport and erect the blocks of stone forming their structures is a puzzle to modern engineers, who with their best appliances, can only lift one-fourth of their weight. They used steel tools, as is shown by the grooves in their quarries, and grappling irons were used to handle the blocks, to which the holes in them attest. All ancient iron was made by reducing pure oxides in a shallow charcoal fire, forming a sponge, and then hammering out the slag, a process carried on to this day.

The oldest and finest of all ruins are at Baalbec, Syria. Their columns, seven feet diameter, in three sections of twenty-four feet each were held together by wrought-iron dowels, but these have been dug out by the Turks and Arabs during the Dark Ages to get material for implements of war and agriculture. They replaced a people of superior intelligence by their rugged nature and strength of muscle, but could not make a pound of iron. In all the Egyptian ruins the same destruction is noted. The massive coping stones of the temples were held together with iron clamps, but they have all been dug out and much of the work of these grand old masters has been destroyed by the lazy, arrogant vandals of the Dark Ages.

To make steel, the ancients submitted wrought iron to the cementation process, which is heating the iron in a closed vessel with carbon at a red heat. In this state it absorbs sufficient carbon to harden it and give it steely qualities. This process is carried on in India to-day.

Aristotle gives us a few notes on iron, but Pliny speaks more freely, thus: "Nature, in conformity with her usual benevolence, has limited the power of iron by inflicting upon it the punishment of rust, and thus displays her usual foresight in rendering nothing in existence more perishable than the substance which brings the greatest danger upon perishable mortality."

He states that the method of making iron is the same as

that employed in making copper, and while some ores produce a metal that is soft and nearly akin to lead, others produce a brittle, coppery iron. Also that "it is a remarkable fact that when the ore is fused the metal becomes liquefied like water, and afterwards acquires a spongy, brittle texture." This can be seen to-day in any Catalan forge, where the slag accumulates, and on tapping off runs like water, leaving behind a brittle, spongy mass, which being consolidated by the hammer, becomes soft and tough. The brittleness is overcome by patting the bloom at first with light blows until it is compacted, then striking heavy blows and drawing it into billets. Also that "iron which has been burned in the fire is spoiled, and is useless until it is forged with the hammer;" this refers to the burned part being worked off in scale and sparks, and that "some iron cannot be worked at a red heat, but must be a bright yellow." This is the modern red-short iron. The iron, he says, "that is used for hob nails is soft like lead," which corresponds to our pure neutral iron, made in the Catalan forge.

The earliest record of furnaces for making molten iron (not sponge) show a hole some 15 inches diameter and 3 feet high in a clay bank. This was filled with charcoal and blown with air caught by deflectors and conveyed to the interior through pipes or reeds. After the furnace was warmed up with the burning coal, charges of ore and coal were put in, and after a few hours a lump of molten iron was taken out of the crucible by tearing the crucible open. This iron contained a little combined carbon, and if it had the right quantity, it could be worked into steel at once, or it could be decarbonized and made into wrought iron. The slag formed in these furnaces was silicate of protoxide of iron from the fusion of part of the ore with the gangue. It was tapped off from the furnace when it accumulated too high.

Carbon exists in iron as combined carbon or as graphitic carbon. Combined carbon makes iron steely or hard; graphitic carbon denotes soft iron. After bellows, made of pig or goat skins and operated by the foot or hand were

invented, higher heats could be obtained. This necessitated the use of more refractory material for the furnace, and caused separate structures to be built. The higher heats gave more combined carbon to the iron, which was worked off in another fire. After the Germans began making iron, they built their furnaces or stuckofens higher to economize heat and save charcoal, as they found wood getting scarce. In these higher furnaces the ore and coal collected the ascending heat and returned it to the crucible, increasing its heat and giving them an iron of different character. Part of the carbon was chemically combined and part was mechanically mixed with the grains, giving the iron a dark color and fluidity so that it would run like molten lead. As this iron was difficult to decarbonize, they called it bad or sow iron.

Prior to the thirteenth century, the art of iron founding was unknown, but with the use of higher furnaces a metal was made that was fluid and could be cast, which soon came into use and formed a new branch of the iron business. As the old German furnaces were small, they run the combined carbon iron out in a long groove made in the sand, as the iron was mushy and flowed with difficulty from the furnace. When they used higher furnaces and made iron with graphitic carbon which ran fluid, they ran short grooves at right angles to the long groove, and filling them with metal, they called them pigs, a practice in use to-day.

By some it is thought the head of the battering-ram used by the ancients was cast iron, but it is too brittle for that purpose; it was forged to the shape shown on ancient monuments. Only rich, pure ores could be used by the ancients. They could not get the intensity of heat in their furnaces to give them graphitic carbon in the iron; hence, they could only make wrought iron.

Among the earliest appliances of cast iron in founding was to make cannon, but they frequently burst in the third or fourth round and killed as many friends as enemies, like some of the canonical laws made at times in the world's progress.

After the iron business had been conducted in England

for many years, the wood becoming scarce, they turned their attention to mineral fuel or coal with more or less success. About 1630 Dud Dudley experimented with coke.

In 1735, Abraham Darbey, of England, made the first successful blast with coke, and from that day to this it has been continued in making pig iron.

In 1837, anthracite came into use for pig iron making in Wales, and is continued in Pennsylvania to the present time.

In 1828, Neilson first applied heated air to the furnace, which raised the temperature of the crucible and allowed a more basic or limy flux to be used. This melts at a high temperature, but picks up the sulphur in the ore and fuel and gives a better iron. With the introduction of hot air, cheaper ores, but containing a higher percentage of sulphur and silica, could be used, which lowered the cost.

The heat of the crucible has been further increased by the use of regenerative stoves giving lower fuel consumption, more output and better iron, as the less fuel used, the less impurity goes from the fuel to the iron.

While metals as a rule increase in value with their purity, pure iron has no commercial existence and is never known outside of the chemical laboratory. Its value is only established when it is combined with carbon, but some of the following elements always accompany it in greater or less quantities and modify its character: silicon, manganese, magnesium, sulphur, phosphorus and aluminum. In chemical combination with iron there is no exact line of demarcation with these elements. Carbon exists in pig iron in the combined or the graphitic state, or in both states. Combined carbon closes the grain of iron, making it smaller and harder. Graphitic carbon is the combined carbon changed by high heat to the graphitic state which softens the iron. Silicon destroys the grain of the iron, making it weaker, softer, and cold-short. Manganese destroys the grain, weakens it and makes it red-short. Magnesium is claimed to soften and strengthen iron. Phosphorus is an unwelcome ingredient which cannot be eliminated and has to be tolerated; it weakens iron and makes it cold-short. Sulphur is

a vigilant enemy, closing the grain, making it harder, and causing red-shortness, but it can be eliminated. Aluminum strengthens and softens iron. Copper makes iron red-short. Cold-short iron will work in the smith's fire at a low heat, but is weak when cold. Red-short iron will work only at a high heat, but is strong when cold. If the iron is not worked at the heat to suit its nature it will crumble or break.

Pig iron is sold in the market in five grades, Nos. 1, 2, 3, 4 and 5. Besides these there are special grades established recently but used extensively, namely: Low phosphorous and sulphur iron used in the open hearth and Bessemer processes, and low silicon with high phosphorous iron, used in the basic process. Silicized iron containing four per cent. to seven per cent. of silicon is also made to soften other irons and make them run liquid.

ANALYSIS OF A STANDARD NO. 1 PIG IRON.

	Per Cent.	
Iron,	92·37	*Gray.* — A large, dark, open-grain iron, softest of all the numbers and used exclusively in the foundry. Tensile strength, low. Elastic limit, low. Fracture, rough. Turns soft and tough.
Graphitic carbon,	3·52	
Combined carbon,	·13	
Silicon,	2·44	
Phosphorus,	1·25	
Sulphur,	·02	
Manganese,	·28	

NO. 2 PIG IRON.

	Per Cent.	
Iron,	92·31	*Gray.* — A mixed large and small dark grain, harder than No. 1 iron, and used exclusively in the foundry. Tensile strength and elastic limit higher than No. 1. Fracture, less rough than No. 1. Turns harder, less tough and more brittle than No. 1.
Graphitic carbon,	2·99	
Combined carbon,	·37	
Silicon,	2·52	
Phosphorus,	1·08	
Sulphur,	·02	
Manganese,	·72	

NO. 3 PIG IRON.

	Per Cent.	
Iron,	94·66	*Gray.* — Small, gray, close grain, harder than No. 2 iron, used either in the rolling mill or foundry. Tensile strength and elastic limit higher than No. 2. Turns harder, less tough and more brittle than No. 2.
Graphitic carbon,	2·50	
Combined carbon,	1·52	
Silicon,	·72	
Phosphorus,	·26	
Sulphur,	trace	
Manganese,	·34	

NO. 4 PIG IRON.

	Per Cent.	
	A.	*B.*
Iron,	94 48	94·08
Graphitic carbon,	2 02	2 02
Combined carbon,	1 98	1 43
Silicon,	·56	·92
Phosphorus,	·19	·04
Sulphur,	·08	·04
Manganese,	·67	2 02

Mottled.—White background, dotted closely with small black spots of graphitic carbon, little or no grain. Used exclusively in the rolling mill. Tensile strength and elastic limit lower than No. 3. Turns with difficulty, less tough and more brittle than No. 3.

[The manganese in this (*B*) pig iron replaces part of the combined carbon, making the iron harder, and closing the grain, notwithstanding the lower combined carbon.]

NO. 5 PIG IRON.

	Per Cent.
Iron,	94 68
Combined carbon,	3 83
Silicon,	·41
Phosphorus,	04
Sulphur,	·02
Manganese,	·98

White.—Smooth, white fracture, no grain, used exclusively in the rolling mill. Tensile strength and elastic limit much lower than No. 4. Too hard to turn and more brittle than No. 4.

Fig. 1, of the plate, shows the fracture of a No. 1 pig of the Thomas Iron Company (as are all the others). The large patches show the grain of the iron, which is rough and projects up in sharp points. On examining it with a powerful glass the grains of iron are found embedded in the graphitic carbon similar to a wall of rubble masonry laid solid in mortar. The grains are connected but the interstices are filled with the graphite. Graphitic carbon high, combined carbon low.

Fig. 2, of the plate, shows the fracture of a No. 2 pig. The patches are smaller, showing a smaller grain. Graphitic carbon lower, and combined carbon higher than No. 1.

Fig. 3, of the plate, shows fracture of No. 3 pig. The patches are smaller than No. 2 and show smaller grain. Graphitic carbon lower, and combined carbon higher than No. 2.

Fig. 4, of the plate, shows fracture of No. 4 pig. The patches are smaller and more of them than in No. 3 and

show little or no grain. Graphitic carbon lower and combined carbon higher than No. 3.

Fig. 5, of the plate, shows fracture of No. 5 pig. The patches are small and closer but no grain. No graphitic carbon, all combined carbon.

The strength for tension culminates in No. 3 pig iron, but falls off more rapidly from No. 3 to No. 5 than from No. 3 to No. 1.

	Per Cent. Combined Carbon.
Malleable iron contains	·25
Steely iron contains	·35
Steel contains	·50
Hard steel contains	1 to 1·50

Taking the sum of the graphitic and combined carbon in each quality of pig iron they are practically the same. The softness of pig iron is dependent on the amount of graphitic carbon in it. Separating the iron in the No. 1 pig from the graphitic carbon, it is a nearly pure wrought iron embedded in the graphitic carbon, and it is the absence of combined carbon which gives it the softness and flexibility that make it desirable for machinery and other purposes.

The grains of iron are crude crystals. When the iron is nearly pure and allowed to cool very slowly, regular octahedral crystals of iron are formed. Fine crystals were found twelve years ago in the hearth of Crown Point Furnace. They used an ore low in phosphorus, sulphur and manganese. These crystals are now in the Academy of Natural Sciences.

No. 1 pig iron may be defined as being composed of grains of wrought iron connected together but embedded in graphite. No. 2 pig iron has more combined carbon, which converts the wrought iron into a soft steel harder to the tool working it. No. 3 pig iron has more combined carbon, and the iron portion is a crude steel harder to the tool working it. Nos. 4 and 5 are virtually crude, high combined-carbon, steels.

The numbers here given, 1, 2, 3, 4, 5, for qualities of pig iron are the old standard. Some founders grade in

given. If the impurities in pig iron were uniform, which would be the case if there were only one kind of ore and fuel, the proper plan would be to buy iron by chemical analyses on a basis of graphitic and combined carbon, but the impurities so change the character that the eye is found to be the best guide so far in fixing the grade. In running the ends of the fingers over the fracture of a pig of iron, if the ends of the grain tear the fingers, the iron is strong. The analysis (B) of No. 4 pig iron, shows low in combined carbon, but the manganese hardens the iron and changes it from gray to mottled iron.

Fig. 6, of the plate, is a hot-blast No. 1 charcoal iron from Grand Rivers, Ky. The pigs bend before breaking. The ends of the grain are sharp and tear the fingers. The analysis is as follows:

	Per Cent.
Silicon,	1·955
Sulphur,	·029
Phosphorus,	·488
Manganese,	·213
Graphitic carbon,	3·310
Combined carbon,	·460
Iron,	93·545

On breaking this iron, the pig when it strikes the breaking blocks, emits a dull thud like lead. It is an iron of high tensile strength and well adapted for making car wheels. There are times in furnace practice when the first iron at a cast runs sluggish and mushy, but the iron on cooling is found to be excellent No. 1. This iron is the first formed directly after casting and lying near the tapping hole has slowly lowered its temperature and formed coarse grained iron. On opening the tapping hole the more fluid iron in the hearth pushes this cooler iron out first and it is then followed by the fluid iron.

The bending of pigs is not confined to charcoal iron. Cake and anthracite iron do the same when using good stock and running the furnace at the proper temperature.

Referring to the pig iron furnace section, *Fig. 7*, the air blown through the tuyere is quickly converted to carbonic oxide gas and the heat from it keeps the fuel in the bosh at

a white heat. The bosh and hearth are always filled with fuel when the furnace is working well. If the heat in the bosh becomes too high from a light burden, the silicon in the fuel is reduced, part of it going to the pig iron, giving a weak, light iron. When silicon is reduced, the cinder will

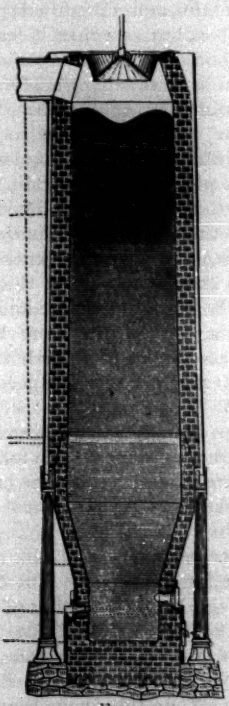


FIG. 1.

not take it up, what escapes the iron is burned to silica in the stoves and boilers; hence the heavy white fumes at the chimney top. Silicized iron was unknown to the ancients for want of heat to produce it. With a good burden of ore the heat of the bosh can be kept at the temperature

six divisions, and in some cases ten to eleven grades are required for a given iron. As the ore reduces in the upper part of the furnace a finely divided carbon penetrates the ore and combines with the iron; when the iron melts out of the ore it leaves it with the carbon in the combined state. As it trickles down through the glowing fuel it may form some graphitic carbon, but as a rule, it reaches the crucible with combined carbon only. With a clean, hot hearth, the carbon in the iron is gradually transformed to graphitic carbon. As the fluid iron running from the furnace cools, more or less of the carbon separates as graphitic carbon which is squeezed into the interstices between the grains as they form. If this pig iron is run against a cold plate the graphitic carbon is changed to combined carbon, and the lower the silicon in the pig iron the harder and greater is the depth of the change. If the thickness of the running iron is too great to change the whole thickness of the pig iron, then part of the pig will be close and hard, while the other part is open and soft. As more burden of ore is applied to the furnace the heat of the bosh and crucible is decreased, and Nos. 2, 3, 4 or 5 is produced as the bosh and hearth get cooler.

In making No. 1 iron, the founder must be careful to keep a large, clean, hot crucible, as the finishing touches to the iron for grade are made in it. In the crucible alone and not above it, must the intensity of the heat be applied to the iron to form graphite.

After the founder has made good No. 1 pig, it is sent to market and bought for the cupola. The cupola is charged with fuel and iron, the No. 1 iron being placed in the lower part of the cupola on a good bed of fuel, above it is more fuel, and on this is laid the harder iron. Suppose it is to make a roll; then No. 3 would be used. Blast is applied to the cupola, it burns up one side more than the other, and the hard iron above melts, comes down and mixes with the good No. 1 meant for pulleys; the result is, both irons are spoiled, and the founder making the No. 1 gets soundly berated for making an iron that changes in remelting.

Again, suppose all No. 1 is charged, and the iron is

melted at a lower temperature than that at which it was made; the carbon will partly change from graphitic to combined carbon, and make the iron harder. Again, suppose the fuel is high in sulphur, the iron, in the absence of the strong basic cinder of the blast furnace will take it up, closing the grain and making the iron harder; or, if the cupola scaffolds on one side, the air rushing up through the contracted opening decarbonizes the shots of falling iron and makes it harder. Iron melted with an excess of fuel will take up the kish or graphite formed by the intense heat, and on pouring the casting the cooling effect of the pouring squeezes out the graphite, which floats to the top of the mould and makes spongy castings. It is important to melt with the proper heat and no excess. Certain sands also exert a bad mechanical influence on pig iron by forming an asbestiform material that floats to the top of the mould, making defective castings.

Iron, to retain its quality as sold, should be melted by gas containing no free air. The gas should be burned to carbonic acid with an excess of air while heating up the iron. As soon as melting begins, the gas should be burned to carbonic acid with a slight amount of carbonic oxide in excess to take care of any truant air entering the furnace door. This can be accomplished by a regenerative furnace, using gas for heating. This furnace is the same as the open hearth furnaces now in use in all our large steel works, and consists of a square building of iron plates, lined with refractory brick and having a basin-shaped hearth on bottom. At each end of the square building are two round iron stoves, filled with fire brick having numerous passages from top to bottom of the bricks, called regenerators. The hearth and regenerators having been warmed up by wood, gas is turned through one of the regenerators and air through the other alongside of it. The gas and air meet at the end of the hearth and burn across it, heating it up and melting the iron placed on the bottom of hearth. After the burned gas passes the hearth, it enters the two opposite regenerators, heating them up. When the two first regenerators begin to cool off, the valves are reversed and the gas

and air sent back over the iron and through the other two regenerators. The burned gas in passing through the two first regenerators heats them up, when another reverse is made, and so on until night. By this arrangement all the waste heat of the furnace is utilized except the heat escaping in the carbonic acid at the chimney, which is about 350°. Comparing this with the 2,000° escaping at the chimney of the cupola, a saving is effected in fuel. It will be safe to take the saving at 100 pounds fuel per ton of iron melted, which will pay the interest on difference of cost between the cupola and open-hearth regenerative plant.

With this furnace, slow or quick melting, and hot or cold melting, can be had at once; no sulphur will be taken up by the iron, and it can be kept at any desired heat, which avoids a change in the original quality. A perfect mixture can be made, as different irons charged when melted can be well stirred through the doors and made homogeneous. No precision of this kind can be obtained with the cupola, as it is guess-work when certain qualities of iron get down to the melting-point, and they cannot be stirred except in the ladle, which may not get equal quantities of each iron. No graphite can be formed in this furnace to make poor castings. An objection to this furnace will be the loss of heat keeping it hot over night with a small volume of gas, but it has the advantage of being ready in the morning for work as soon as the men arrive. As the high heat used in open hearth steel plants is not required for melting pig iron, the loss in heat to keep furnace warm over night would be slight. With the improved cranes and appliances for handling the metal, there is no longer need of suspending all moulding while pouring. When this system is taken up and worked out carefully in all its details, it will prove a decided success, as moulding and pouring can go on side by side.

From the data now being collected by the different iron works, some active brain in the future will give the world a table, showing how each element affects the pig iron, and by it a founder will be enabled to make his mixture to

produce the required results without having recourse to trial for each brand of pig iron.

The blast furnace is still in its infancy, yet in this country it has made rapid strides, and gone far beyond Europe in output and low fuel consumption.

THE PRESENT STATUS OF THE STORAGE BATTERY SYSTEM OF STREET RAILWAY PROPULSION.

BY PEDRO G. SALOM.

[*Read at the stated meeting of the Franklin Institute, held June 15, 1892.*]

JOS. M. WILSON, President, in the chair.

MR. SALOM: A distinguished scientist once told me that many years ago he was invited to give his first public lecture. He chose a subject that he thought he was very familiar with, as it was one in which he had been making long and careful investigations, but much to his amazement, after talking for ten or fifteen minutes, he found that he had exhausted the subject, and had told his audience all that he knew about it. Then he said he began to repeat himself, and he had continued to repeat himself ever since. Personally I am in very much the same position. I feel that I have already told all that I know about storage batteries, except what has been already better told by others. Still an old truth presented in a new light sometimes carries conviction for the first time.

This, then, is my reason for being here this evening. In discussing "The Present Status of the Storage Battery System of Electric Street Railway Propulsion," there are three questions to be considered:

(1) Why is it that so promising a field in electrical engineering has as yet produced no adequate commercial results?

(2) What definite knowledge has been gained by the trials and failures of the past? and

(3) What are the prospects for the future for the introduction of storage battery traction?

Now, in respect of the first question, I would say that undoubtedly the dreadful patent litigation in which the whole subject of storage batteries has been involved is largely responsible for the failures in the past, although there are other causes which I will touch on presently.

I will not burden you with a history of the patent litigation, which has now extended over a period of five years and which has been prosecuted with a degree of vigor and intensity (and I might even say malignity) worthier of a better cause, further than to say, that the fundamental principle upon which all forms of storage batteries are constructed has been thrice awarded to Chas. F. Brush in the lower courts, and the case is now before the court of last resort, whose decision may be expected at any time, and which, of course, will be final. The fundamental principle just referred to is the broad claim for the application of the active material to a conducting support.

This uncertainty, therefore, of the ownership of the basic patents has rendered capital timid. Conservative street car companies could not afford to equip their lines with a system that might be adjudged an infringement of others' patents, and upon which an injunction might issue at any time, and on the other hand the battery companies have not been in a strong enough financial position to properly equip and operate a line of sufficient magnitude to demonstrate the practicability and commercial success of their respective systems, or at all events if they have been, they have utterly failed to do so.

I might add, also, that as a further result of this doubt or uncertainty as to the ownership of the patents, a large number of storage battery companies have sprung up in all parts of the country without any possible reason for their existence beyond the fact that their promoters thought that it was only necessary to change the shape or form of a

plate to escape the patents and for the further purpose of selling stock to the innocent public.

Many of these attempts show an utter ignorance and disregard of all the principles that are well known on the subject.

Thousands, yes, hundreds of thousands of dollars have been squandered in this way, much to the sorrow and disappointment of the many innocent stockholders, and to the dismay and confounding of the general public, who, seeing so many failures, have come at last to doubt the practicability, or even possibility, of a commercial battery. We, however, have nothing to do with this. The success or failure of an engineering problem, fortunately, does not depend upon what the general public may think about it, unless it be a problem requiring an enormous capital, which can only be obtained through the Government or by the coöperation of a large number of individuals. What, then, does it depend on? It depends on our ability to demonstrate that we can accomplish a desired result in a better and cheaper way than has heretofore been employed.

This brings us, then, to our second query.

What definite knowledge has been gained by the trials and failures of the past?

This, of course, is a vast subject of inquiry, as it embraces our entire experience during the past six years, and my time will only permit me to dwell on the essential features.

Assuming, now, for the sake of argument, that electric storage traction is practicable, what are the problems that confront the engineer?

The first and most important is the life of the battery.

(2) The capacity.

(3) The rate of discharge.

(4) The weight and size of the elements.

(5) The loss of power in the various transmissions between the prime mover and the axle; or, in other words, the relative efficiency compared with other methods.

(6) The distance or total length of line.

(7) The grades and curves.

(8) The speed.

We will not consider all these points separately, but the whole question in a general way.

In traction work there is only one reliable method of determining the life of the battery, and that is on the basis of car mileage. It is all nonsense to talk about batteries lasting eight months or eighteen months, unless there is a record at the same time of the amount of work accomplished, measured in electrical horse-power hours. The highest record yet obtained, that I have any reliable knowledge of, is that of a single set of 108 accumulators making over 6,000 miles. This record was made on the Citizen's Passenger Railway, in Indianapolis, and was made under the most trying and unfavorable circumstances.

Assuming that the battery could make 100 miles per day, this would mean that the battery would have to be renewed every sixty days. If fifty miles per day, then the life would cover a period of four months; and at twenty-five miles per day, eight months, etc. So you can readily understand that the bare statement that a battery would last six or eight months does not convey a correct idea of the real life of the battery.

Let us see what it would cost to run 6,000 miles with a single set of accumulators, or since two sets are always employed, the one being charged while the other is in service, we will make the calculation on a basis of 12,000 miles.

216 positive groups, at $2.50, ...	=	$540 00
Credit 2,592 pounds lead scrap at 3 cents	=	77 76
Balance, ...		$462 24

462·24 ÷ 12,000 = 3·85 cents per car mile.

What amount of work is represented by this 6,000 miles, so far as the accumulators are concerned?

It was found by keeping the most careful records on the Fourth Avenue Line in New York, that the amount of energy consumed per car mile was about one and one-half E. H. P. hours. That is to say, that after making a round trip of eleven and one-half miles, it required about seven-

teen E. H. P. hours to replace the energy drawn from the batteries. Six thousand miles would, therefore, require 9,000 E. H. P. hours, and since a battery of 108 cells has a capacity of fifty-four E. H. P. hours for each total discharge, if we divide $9{,}000 \times 54$ we get 166 discharges that are required of the battery, before the positive plates break down. Any one who has had any extensive experience with storage batteries knows that this is a very conservative estimate of the amount of work that a good battery will perform.

It may be asked, have there been no improvements in late years with a view of diminishing the number and weight of batteries required to propel a car? I regret to have to answer, no, and this brings me to the consideration of the limitations of storage batteries.

I have said that it requires about one and one-half E. H. P. hours per car mile, and that 108 accumulators are used and necessary for a twelve-mile run, and they have a capacity of fifty-four E. H. P. hours, or three round trips.

Why is it not possible to use a battery with one-third the weight? Simply because the weight of battery required is not according to the total amount of work to be done, but according to the rate at which it is to be done.

Let us go back to our twelve-mile run again. This requires one and one-half E. H. P. hours per car mile, or, 1,119 watt hours, and since the E. M. F. is about 225 volts, this would be equivalent to nearly five ampère hours per mile, or sixty ampère hours for the round trip; and since the trip consumes two hours' time, this is an average rate of discharge of thirty ampères all the time.

Of course, it is very much greater than this at times, when the car starts or is going up steep grades, etc., when the battery is frequently called upon for a rate of discharge of over 100 ampères.

Now, if we were to use a smaller battery of less total capacity, there would not be sufficient surface area of active material exposed to develop such a current, the E. M. F. would drop and the car stop running. This is the trouble with all thick plate batteries. The amount of surface area exposed is comparatively small for the weight of battery.

A reference to the following diagram, showing the curves of discharge (at 100 ampères) of four types of accumulator, will illustrate very forcibly why thick plate batteries are not available for traction purposes.

The first two curves are from thin plate batteries, and the second two from thick plate batteries, all tested under the same conditions.

This comparison is not intended as a disparagement of the thick plate batteries, the Donaldson-Macrae type in particular having a number of very valuable features embodied in its construction, but it is only designed and intended for compartively low rates of discharge.

It will be observed that in the thick plate batteries that the E. M. F. falls in one case to 1·5 volts in twenty-three minutes, while in the second case, although it falls more rapidly at first than the former, it maintained the current ten minutes longer before a fall to 1·5 volts was reached.

When the E. M. F. falls below two volts per cell the efficiency of the motor begins to fall *pari passu*.

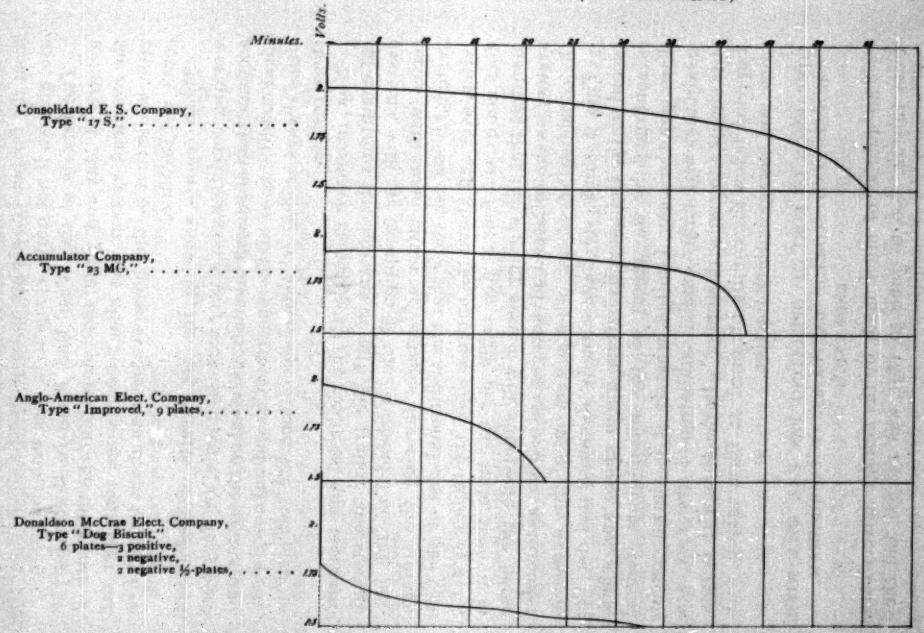
Finally, we come to the consideration of the prospects for the future of storage traction.

It seems to me, in view of the facts which I have just stated, and which are indisputable, that the introduction of storage traction for surface roads in our large cities is inevitable.

The trolley may be introduced at the present time, pending the solution of the difficulties under which storage batteries have come into disrepute, but that it can obtain in the long run against the many and obvious advantages of the storage system is incredible. Let the public once understand that there are no insurmountable difficulties connected with the storage system, beyond the fact that it costs a few cents more per car mile than the trolley, and the demand for its introduction will be irresistible.

The public are not interested in the cheapest and most objectionable method of transit, especially where they derive no benefit from the economies effected, but they are interested in and entitled to a safe, reliable and absolutely unobjectionable method of transit, which is cheaper than

DISCHARGE OF ACCUMULATORS AT 100 AMPÈRES (RATE MAINTAINED).


Volts.
Minutes.
Consolidated E. S. Company, Type "17 S,"
Accumulator Company, Type "23 MG,"
Anglo-American Elect. Company, Type "Improved," 9 plates,
Donaldson McCrae Elect. Company, Type "Dog Biscuit," 6 plates—3 positive, 2 negative, 2 negative ½-plates,

horses at the present time, and which may in a few years, from the further knowledge and experience gained by actual use, almost, if not quite, compete in cost with the trolley.

The reports of the West End Road in Boston for the months of May and June, 1891, show that the total cost of the overhead system was about twenty-one cents per car mile, while that of the horse system was about twenty-five cents per car mile.

These reports, showing the net results of the actual working conditions on a very extensive scale, are far more accurate than any paper calculations based on theoretical and ideal conditions, as all the uncertainties and unknown quantities always arising in actual operations are included in these results.

Now, inasmuch as nearly all the electrical and mechanical conditions are constant in both the trolley and storage systems, with the exception of the overhead line and batteries (with some minor advantages favoring the storage system,) if we can show that the additional cost of the batteries, over and above the entire cost of the trolley system, does not exceed four or five cents per car mile, then it is manifest that the storage system will supersede the horse system, as the collateral advantages are so great as to render the consideration of any other system out of the question.

This, I think, we have already demonstrated by the record of the Indianapolis battery given above, and which is confirmed by the report of the Birmingham Central Tramway Company, Limited, wherein it is shown conclusively that with only a small installation of five or six cars, it is cheaper to run with storage batteries than with horses. I append below the results obtained at Birmingham with horse and storage battery traction.

COMPARISON OF COST OF OPERATING PER CAR MILE WITH HORSES AND STORAGE BATTERIES AT BIRMINGHAM, ENGLAND.*

The number of miles made by the storage battery cars, from July 24, 1890, to June 30, 1891, was 138,396, and they

* *Electric Review* (English), August 14, 1892.

carried 1,144,718 passengers. If five cars were in service, this would make nearly 28,000 miles per car.

The gross revenue was	£8,732
The gross expenditures,	5,711
Balance	£3,021

STORAGE BATTERY TRACTION.

Electric Haulage.

	Pence.	
Wages,	2·6	
Fuel,	1·66	
Stores,	·73	
Water and lighting,	·07	
Sundries,	·09	
		5·15
Machinery.		
Material,	·29	·29
Car Repairs.		
Wages,	·6	
Material,	1·33	
		1·93
Total traction expenses,		7·37

HORSE TRACTION.

	Pence.	
Wages,	2·44	
Forage and bedding,	3·72	
Veterinary and shoeing,	·40	
Water and gas,	·06	
Harness repairs,	·16	
Stable utensils,	·04	
Sundries,	·08	
Renewals,	·43	
		7·33
Repairs.		
Wages,	·28	
Material,	·26	
		·54
Total,		7·87

From which it appears that the total cost for storage battery traction was 7·37 pence or 14·74 cents per car mile, and for horse traction was 7·87 pence or 15·74 cents per car mile, and I would call special attention to the fact that, under the heading car repairs, the item of material is only 1·33 pence, or 2·66 cents per car mile, and assuming that this was all for renewals of battery (although, of course, some of the expense must have been for repairs to motors, etc.), we find that the cost of battery renewals (really the only unknown quantity in this problem), was only 2·66 cents per car mile. In view of such facts, is it possible to contend any longer that storage battery traction is not commercial?

I have purposely refrained from discussing the subject except from the one point of view—the storage battery. Every one knows that electric traction is a brilliant and phenomenal success and in advocating the storage system, we are merely proposing to furnish current to the motors,

indirectly by means of a battery instead of directly through a central station.

Of course, the same problems obtain in regard to gearing and motors, etc., in both systems and do not enter into the question as propounded.

In my judgment the storage battery has a future. You cannot pound the life out of a fact. All the slander and ridicule that has been heaped upon storage batteries does not alter their capacity to do a certain amount of work at a given cost, one ampère second.

Give the storage battery a chance. Let the same engineering skill and ability be applied to the storage system as has already been done with the trolley, and the results will be surprising.

On the Specific Heat of Brines of Different Specific Gravity.*

By Dr. Hans von Strombeck.

[*Read by title.*]

If in refrigerating plants the cooling effect is not done directly by the evaporation of the liquid, almost always brine, a solution of sodium chloride (salt) in water is used for transmitting the cold generated in the expansion coils to the place where the cooling effect is wanted. In order to be able to calculate the quantity of a brine of a certain concentration which is required for transmitting the cold generated, the specific heat of the brine must be known. Since the exact values for the specific heat of brines of different specific gravities were not yet known, I determined them by a series of tests. The results showed that the figures obtained from the tests for a certain brine differs more or less from, but is always less than, the figures we obtain by calculating the specific heat of the same brine from its contents of water and sodium chloride.

* From the Laboratory of the De La Vergne Refrigerating Machine Co.

In the following table I give the figures obtained from the tests:

Specific Gravity of the Brine at 60° F.	The Figures in the Preceding Column being its Specific Gravity, the Brine contains Per Cent. of Salt.	Specific Heat of the Brine Calculated from its Contents of Water and Salt, the Specific Heat of the Latter taken to be 0·228.	Determined Specific Heat of the Brine, each Figure being the Average of Four Determinations well agreeing with one another.
1·0250	3·4496	0·9734	0·96440
1·0375	5·1698	0·9600	0·94284
1·0500	6·8547	0·9471	0·91561
1·0625	8·5377	0·9340	0·89798
1·0750	10·2165	0·9213	0·87819
1·0875	11·8569	0·9085	0·86295
1·1000	13·4962	0·8958	0·85610
1·1125	15·1313	0·8831	0·84233
1·1250	16·7036	0·8710	0·82810
1·1375	18·2864	0·8588	0·81998
1·1500	19·8649	0·8466	0·80631
1·1625	21·3871	0·8349	0·80050
1·1750	22·9030	0·8232	0·79417
1·1875	24·4199	0·8116	0·78936
1·2000	25·8884	0·8001	0 78633

From the graphic representation, it can still better be seen how the specific heats, calculated and determined, differ in a different degree from one another.

The tests were made in the following manner:

The apparatus* (see *Fig.* 1), which I think was first designed by Regnault, is made of brass. Tank *A B C D* is filled to such an extent with water that the end *a* of pipe *a b* dips into the water about one inch. By means of the burners *B' B''* the water in *A B C D* is kept boiling. The steam developed escapes through the pipes *F B* and *E G*, and circulates in the drum *F H I K*. In order to lessen the cooling influence of the air and the loss of heat by radiation, the drum is surrounded by a lagging, the tank and the

* I used this apparatus also for the determination of the specific heat of liquid ammonia (vol. cxxx, No. 780, of this journal) after I had made some alterations.

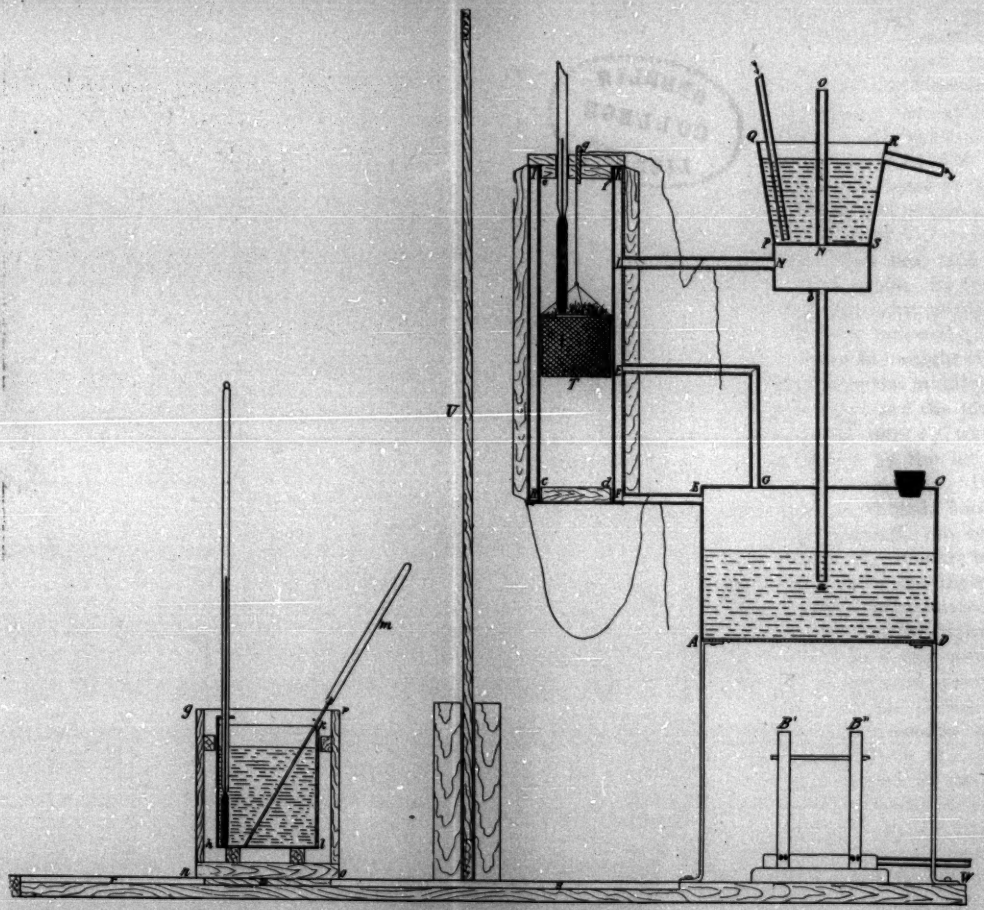


FIG. 1.—Sectional view of the apparatus.

Graphic representation of the specific heat of brines of different specific gravity.

pipes are polished as brightly as possible. One portion of the steam developed in *A B C D* while passing the pipes and circulating in the drum is condensed and flows back to tank *A B C D*; another portion escapes through pipe *L M N O*. Pipe *L M* is enlarged into a box, into the bottom of which pipe *a b* empties, the top of it being connected with pipe *N O*. Pipe *N O* is surrounded by box *P Q R S*. This box is always kept filled with cold water from the hydrant which supplies the same at the bottom of the box, the warm water flowing out at the top. Thus the steam, while escaping through *L M N O* is condensed and through the pipe *a b* trickles down into tank *A B C D*, where it is transformed into steam again. By this arrangement steam can be developed by the same quantity of water for days without its needing to be renewed. The brass-wire basket *T* filled with brass tacks, the weight of which, both together, is known, is suspended in the middle of the cylinder *c d e f* by means of a silk thread and the plug *g*. The top of the cylinder is closed by the cover *e f*, which is tightened by a rubber ring, the bottom by the lid *c d*, which is covered on the inside by a wooden plate. It can be opened and closed by means of a thread, hook and hinges. The thermometer going through the cover, and also being tightened by a rubber ring, reaches to the top of the brass basket. The dimensions of the thermometer are taken in such a way that 0°·01 can be estimated, and that the column of mercury, when indicating the highest temperature which can be produced in *c d e f* only projects a little over the cover. Thus the temperature prevailing in the cylinder can directly be read on the thermometer, and no correction is necessary. The wooden partition *U*, which is intended to keep away from the calorimeter *h i k l*, any influence of the heat caused by the burners *B' B''*, can be moved forwards and backwards between two posts.

The brass calorimeter *h i k l*, the weight of which is known, is filled with a weighed quantity of the brine, the specific heat of which is to be determined. It is provided with a thermometer, and the agitator *m*, by means of which the temperature of the brine is equalized in all parts.

The dimensions of the former again are taken in such a way that 0°·01 can be estimated, and that the column of mercury, when indicating the temperature of the brine in the beginning of the test, does not project much over the surface of the same. Calorimeter *h i k l* is put in the wooden box *n o p q*. The board *V W*, which supports the whole apparatus, has the groove *r s* in its longitudinal extension. Box *n o p q* having at its bottom the projecting board *u* fitting groove *r s*, can easily be made to slide forward and backward under the cylinder *c d e f*, after partition *U* has been moved backwards. After the apparatus is properly adjusted, the burner B_I B_{II} are lit. When the thermometer in *c d e f* indicates a constant temperature, the temperatures indicated by each thermometer and the time are noted down, partition *U* is moved backwards, lid *c d* swung open, box *n o p q* slid under cylinder *c d e f*, basket *T* lowered into calorimeter *h i k l*, box *n o p q* slid back, partition *U* removed into its previous place, and the ascension of the thermometer in the calorimeter *h i k l* is watched. As soon as it begins to go down, the time is noted down again, thus giving us the number of seconds during which the thermometer ascended. From the moment it begins to descend, during some minutes the temperatures indicated by the thermometer every sixty seconds are noted down. From the figures thus obtained, the specific heat of the brine can be calculated.

Further below, I give the four authentic proofs for the determination of the specific heat of brine of 1·1875 specific gravity. In the following I shall add to each item the figures obtained from the third of these four tests.

If *M* means the weight of brass tacks and basket together (446·0 grammes);

σ means the specific heat of brass (0·0939);

m means the weight of the brine filled into the calorimeter *h i k l* (510·0 grammes);

T means the temperature prevailing in cylinder *c d e f* (95°·771 Cels.);

τ means the temperature of the brine indicated by the thermometer at the beginning of the test (21°·20);

τ_1 means the temperature of the brine indicated by the thermometer at the end of the test (28°·05);
x means the specific heat of the brine that is to be determined;

we arrive at the following equation:

$$x\,m(\tau_1 - \tau) = \sigma\,M(T - \tau_1) \qquad (1)$$

In this equation we did not take into consideration the heat which is absorbed by the brass of the calorimeter *h i k l*, and the thermometer in it for being heated up from τ to τ_1 degrees.

If μ means the weight of the brass calorimeter (75·2 grs.);
μ_2 means the weight of the thermometer in it;
σ_2 means the specific heat of the thermometer, and these values are introduced into equation (1);

we obtain equation

$$x\,m(\tau_1 - \tau) + \sigma\,\mu(\tau_1 - \tau) + \mu_2\,\sigma_2(\tau_1 - \tau) = \sigma\,M(T - \tau_1) \qquad (2)$$

$\mu_2\,\sigma_2$ is determined in the following manner: The thermometer is put in warm water, then put in a weighed quantity of cooler water and it is observed what temperature the water has obtained by the bringing in of the thermometer.

If θ means the temperature of the thermometer when put in the water;
ϑ means the temperature of the water before the thermometer was put in;
ϑ_1 means the temperature of the water after the thermometer had been put in;
m_1 means the weight of the water;

we obtain

$$\sigma_2\,\mu_2(\theta - \vartheta_1) = m_1(\vartheta_1 - \vartheta)$$

or

$$\sigma_2\,\mu_2 = \frac{m_1(\vartheta_1 - \vartheta)}{\theta - \vartheta_1}$$

The value for $\sigma_2 \mu_2$ is the same in all tests. The observations having been:

θ, ...	= 29°·84	29°·18	29°·77	29°·78
ϑ, ...	= 20° 85	20°·74	20°·80	20°·82
ϑ_1, ...	= 23°·06	22°·67	22°·86	22°·96
m_1, ...	= 5·7 grs.	5·7 grs.	5·7 grs.	5·7 grs.
we find $\mu_2 \sigma_2$ =	1·86 grs.	1·67 grs.	1·69 grs.	1·78 grs.

average of $\mu_2 \sigma_2$ . . . . . = 1·75 grs. of water.

But we have to make one correction more. In these equations we admitted the difference $\tau_1 - \tau$ to be in reality

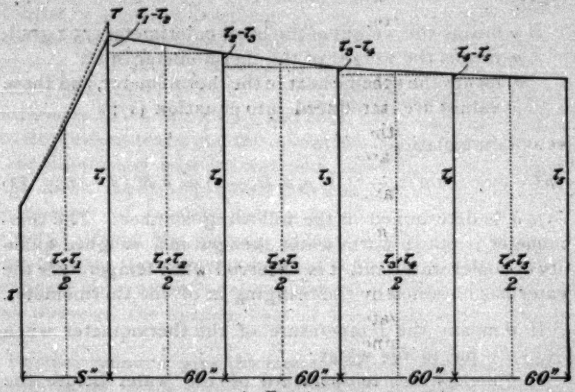


FIG. 2.

all the heat given by the brass tacks and basket to the brine in the calorimeter, to the calorimeter itself and to the thermometer in it. But this supposition is not true, as during the tests the brine, calorimeter and thermometer lost heat by radiation and by the cooling influence of the air. Without this loss of heat the thermometer would not only have gone up to τ_1 degrees (see *Fig. 2*), but a little more, to $\tau_1 + \delta$ degrees. This δ is determined in the following manner:

It took s seconds (45″) to raise the temperature of the brine from τ to τ_1 degrees. Then after having stopped a moment, the thermometer began to go down. It went

down in the first sixty seconds from τ_1 to τ_2, in the next sixty seconds from τ_2 to τ_3, from τ_3 to τ_4, from τ_4 to τ_5, or the decreases were $\tau_1 - \tau_2$, $\tau_2 - \tau_3$, $\tau_3 - \tau_4$, $\tau_4 - \tau_5$, the values

$$\frac{\tau_1 + \tau_2}{2} \qquad \frac{\tau_2 + \tau_3}{2} \qquad \frac{\tau_3 + \tau_4}{2} \qquad \frac{\tau_4 + \tau_5}{2}$$

representing the average temperatures prevailing during each sixty seconds. It is:

$$\tau_1 - \tau_2 = \frac{\tau_1 + \tau_2}{2} \cdot 60 \cdot k_1$$

$$\tau_2 - \tau_3 = \frac{\tau_2 + \tau_3}{2} \cdot 60 \cdot k_2$$

$$\tau_3 - \tau_4 = \frac{\tau_3 + \tau_4}{2} \cdot 60 \cdot k_3$$

$$\tau_4 - \tau_5 = \frac{\tau_4 + \tau_5}{2} \cdot 60 \cdot k_4$$

If we dissolve these equations for k, we obtain

$$k_1 = \frac{2(\tau_1 - \tau_2)}{(\tau_1 + \tau_2)60}$$

$$k_2 = \frac{2(\tau_2 - \tau_3)}{(\tau_2 + \tau_4)60}$$

$$k_3 = \frac{2(\tau_3 - \tau_4)}{(\tau_3 + \tau_4)60}$$

$$k_4 = \frac{2(\tau_4 - \tau_5)}{(\tau_4 + \tau_5)60}$$

and by taking the average of $k_1\ k_2\ k_3\ k_4$, the value of k, *i. e.*, of a coëfficient, which multiplied by the number of seconds which the test lasted, and by the average temperature prevailing during each second, gives the fraction of a degree δ by which more the thermometer in the calorimeter would have gone up, if there had been no loss of heat by radiation and by the cooling influence of the air.

The average temperature during the s seconds (45″) while the thermometer ascended having been

$$\frac{\tau + \tau_1}{2} \text{ degrees,}$$

we have

$$\delta = \frac{\tau + \tau_1}{2} \cdot s \cdot k$$

or the real number of degrees by which the brine in the calorimeter was heated up was $\tau_1 + \delta - \tau$ degrees.

We observed

$\tau = 21°{\cdot}20$

$\frac{\tau + \tau_1}{2} = 24°{\cdot}625 \qquad s = 45''$

$\tau_1 = 28°{\cdot}05$

$\tau_1 - \tau_2 = 0°{\cdot}10$

$\tau_2 = 27°{\cdot}95$

$\tau_2 - \tau_3 = 0°{\cdot}05$

$\tau_3 = 27°{\cdot}90$

$\tau_3 - \tau_4 = 0°{\cdot}04$

$\tau_4 = 27°{\cdot}86$

$\tau_4 - \tau_5 = 0°{\cdot}02$

$\tau_5 = 27°{\cdot}84$

Introducing these figures into the equations above-mentioned, we obtain

$$\left.\begin{aligned} k_1 &= 0{\cdot}000060 \\ k_2 &= 0{\cdot}000030 \\ k_3 &= 0{\cdot}000024 \\ k_4 &= 0{\cdot}000012 \end{aligned}\right\} k = 0{\cdot}000031$$

Hence follows $\delta = 24{\cdot}625 \,.\, 0{\cdot}000031 \,.\, 45 = 0°{\cdot}034$ and $\tau_1 + \delta = 28°{\cdot}084$ and $\tau_1 + \delta - \tau = 6°{\cdot}884$.

Introducing this correction into equation (2) we obtain equation

$$x\, m\, (\tau_1 + \delta - \tau) + \sigma\, \mu\, (\tau_1 + \delta - \tau) + \sigma_2 \mu_2 (\tau_1 + \delta - \tau) = \sigma\, M\, [T - (\tau_1 + \delta)] \qquad (3)$$

and by dissolving it for x we have

$$x = \frac{\sigma\, [M\, (T - (\tau_1 + \delta)) - \mu\, (\tau_1 + \delta - \tau)] - \mu_2 \sigma_2 (\tau_1 + \delta - \tau)}{m\, (\tau_1 + \delta - \tau)}$$

$$= 0{\cdot}79053$$

AUTHENTICAL PROOFS FOR THE SPECIFIC HEAT OF BRINE OF 1·1875 SP. GR.

	I.	II.	III.	IV.
M,	446·0 grs.	446·0	446·0	446·0
μ,	75·2 "	75·2	75·2	75·2
σ,	0·0939	0·0939	0·0939	0·0939
$\mu_2\ \sigma_2$,	1·75 grs.	1·75	1·75	1·75
m,	510·0 "	510·0	510·0	510·0
T,	95°·74	95·85	95·77	96·04
τ,	21°·36	21·84	21·20	21·50
τ_1,	28°·20	28·62	28·05	28·36
τ_2,	28°·15	28·57	27·95	28·27
τ_3,	28°·12	28·54	27·90	28·20
τ_4,	28°·11	28·50	27·86	28·16
τ_5,	28°·10	28·46	27·84	28·12
$\tau_1 - \tau_2$,	0°·07	0·05	0·10	0·09
$\tau_2 - \tau_3$,	0°·03	0·04	0·05	0·07
$\tau_3 - \tau_4$,	0°·01	0·04	0·04	0·05
$\tau_4 - \tau_5$,	0°·01	0·03	0·02	0·04
k,	0·000018	0·000017	0·000031	0·000037
s,	60"	100	45	50
δ,	0°·0268	0·043	0·034	0·045
$\tau_1 + \delta$,	28°·2468	28·663	28·084	28·405
$\tau_1 + \delta - \tau$,	6·8868	6·823	6·884	6·905
$T - (\tau_1 + \delta)$,	67·4932	67·187	67·686	67·635
χ,	0·78778	0·79180	0·79053	0·78732

Average of χ, ... 0·78936

This average value differs from the highest value obtained, ... 0·31 per cent.
This average value differs from the smallest value obtained, ... 0·26 per cent.

If we have to determine the specific heat of a solid body which is soluble in water (in this case salt), we put a weighed quantity of it in the basket T which, of course, is to be made of brass sheathing in this case, and in the calorimeter $h\ i\ k\ l$ a liquid which does not dissolve the body (in this case mineral oil), and the specific heat of which is known.

If M_1 means the weight of the salt, filled into the basket;

m_1 means the weight of the mineral oil;

σ_1 means its specific heat;

μ_1 means the weight of the empty brass basket;

x_1 means the specific heat of the salt that is to be determined, the other letters having the same meaning as formerly;

we arrive at the following equation:

$$x_1 = \frac{\sigma_1 m_1 (\tau_1 + \delta - \tau) + \mu_2 \sigma_2 (\tau_1 + \delta - \tau) + \sigma [\mu (\tau_1 + \delta - \tau) - \mu_1 (T - (\tau_1 + \delta))]}{M_1 (T - (\tau_1 + \delta))}$$

I obtained as average figure of the specific heat of salt 0·228.

ADDITIONAL NOTES ON THE COMPOSITION OF THE LIQUID AMMONIA OF THE TRADE, ETC.

By Dr. Hans v. n Strombeck.

A few weeks ago, just after my paper "On the Composition of the Liquid Ammonia of the Trade" had been presented to the Chemical Section of the Institute, Mr. Louis Block, Chief Engineer of the De La Vergne Refrigerating Machine Company, showed me a piece of a black, dough-like paste which had been scraped out of the compressor of a refrigerating machine. He said that this paste had interfered with the proper working of the valves of the compressor, and thus with the proper working of the whole plant, and requested me to ascertain how this paste could have been formed, and how its formation could be prevented. The weight of the paste scraped out was only 35·24 grains or about one-twelfth ounce. As a superficial examination of the paste showed the presence of a considerable percentage of iron, I thought first that the mineral oil used in the compressor might contain some mineral acid or some fatty oil which by setting free fatty acid had acted on the valves of the compressor. But an examination of the oil used proved it to be pure mineral oil of the same chemical and physical

properties as usual. I then made a thorough analysis of the black paste; that is to say, as thorough as the small available quantity of substance allowed.

The 35·24 grains of the black paste consist of:

Grains.		*Per Cent.*	
3·0860	=	8·7565	of moisture.
4·2278	=	11·9965	of mineral oil.
0·0092	=	0 0260	of ammonium-sulphide.
0 1137	=	0·3227	of sulphate of ammonia.
0·0779	=	0·2210	of ammonium-chloride.
6·2489	=	17·7324	of organic matter soluble in water.
6·5302	=	18·5301	of peroxide of iron.
0·7601	=	2·1569	of iron-sulphide.
14·1862	=	40 2579	of (by difference) insoluble organic matter.
35·2400		100 0000	

The kind of bodies found made me suppose that the formation of the black paste is due to the action of impurities contained in the liquid ammonia on the valves and the oil in the compressor, and the analyses of five liquid ammonias, which had been made of different raw materials and by different processes, prove that my supposition was correct:

	G. *Per Cent.*	*H.* *Per Cent.*	*I.* *Per Cent.*	*K.* *Per Cent.*	*L.* *Per Cent.*
Ammonia (by difference), . .	97·9260	98·8040	99·9304	99·9449	99·3115
Colorless fluid, ...	1·4322	0 9734	0·0307	0·0084	0·0270
Moisture, ...	0·5882	0·1962	0·0281	0·0260	0·0266
Mineral oil, ...	0·0158	0·0120	0·0032	0·0038	0·0108
Hartshorn salt of ammonia, .	0·0304	0·0094	0·0064	0·0159	0·0235
Ammonium-sulphide, ...	0·0008	0·0033	0·0002	0·0005	0·0002
Sulphate of ammonia, ...	0·0042	0·0014	0·0004	0·0005	traces
Ammonium-chloride, ...	0·0002	0·0003	traces	traces	0·0004
Mineral matter suspended, . .	0 0022	0·0002	0·0006	traces	traces
	100·0000	100·0000	100·0000	100·0000	100·0000

Sample *L* contains also some resinous matter. Now it seems impossible that such small quantities of ammonium-sulphide and chloride, sulphate and carbonate of ammonia as found in these ammonias can destroy enough iron and oil to explain the presence of the black paste. For, if we take a plant in which 2,000 pounds of such ammonia as analyzed under *G* circulate, the contaminations contained in the 2,000 pounds can only eat off 0·44 pounds of iron. By distributing this loss of iron over the whole interior surface of the pipes, etc., of the plant; that is to say, over a surface

of 1,000 square feet and more, it will be seen that the loss undergone by the valves is only infinitesimally small. Thus the damage done by these contaminations would be equal to nothing if the reaction between the acids contained in them and the metal took place only *once* and stopped as soon as the formation of the neutral salt had taken place. But this is not so. By the electricity generated by the working of a refrigerating plant the sulphate and carbonate of ammonia, the ammonium-sulphide and chloride are decomposed, their acids combining with the iron of the pipes, etc., and decomposing the oil. The iron salts thus formed afterwards dissolve in the water, always sufficiently present, and in the ammonia and are transformed again into sulphate, etc., of ammonia, the iron being separated out and being more or less oxidized by the oxygen of the air, which is always present in small quantities. The newly formed sulphate, etc., of ammonia is decomposed again by the electric current, and so on, a continuous circuit being formed. In this way by a very small quantity of impurities of this kind, considerable quantities of iron and oil, can be destroyed and the proper working of the plant interfered with, the latter so much more, as in its most sensitive point in the compressor the action of the acids is most energetic because of the high temperature (150°) prevailing there.

To avoid the formation of such a black paste and its unpleasant consequences it is therefore necessary to use in a refrigerating machine only such liquid ammonias out of which all ammoniacal salts have been removed. While this removal can be done in different ways, my new process of purifying ammonia (described in the July number of this journal) simultaneously with the other impurities stated, also takes these ammoniacal salts out, the reactions being the same as described in equation (III) viz:

$$\text{(IV)} \quad (NH_4)_2\,So_4 + Na_2 = Na_2\,So_4 + 2NH_3 + H_2$$

$$\text{(V)} \quad (NH_4)_2\,S + Na_2 = Na_2\,S + 2NH_3 + H_2$$

$$\text{(VI)} \quad 2NH_4\,Cl + Na_2 = 2NaCl + 2NH_3 + H_2$$

LABORATORY OF THE
DE LA VERGNE REFRIGERATING MACHINE COMPANY,
NEW YORK, July 18, 1892.

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

North, S. N. D. *The Wool Book*. Boston: Rockwell & Churchill. 1892. 16mo.

Peabody, C. H. *Valve Gears for Steam Engines*. New York: J. Wiley & Sons. 1892. 8vo. $2.50.

Picon, R. V. *Distribution de l'Électricité par usines centrale*. Paris: Gauthier-Villars. 1892. 12mo. 3 francs.

Railway Official's Directory. Chicago: *Railway Age*. 1892. 32mo.

Tesla, N. *Experiments with Alternate Currents of High Potential and High Frequency*. New York: W. J. Johnston Company. 1892. 16mo. $1.

Witz, A. *Thermo-dynamique à l'usage des Ingenieurs*. Paris: Gauthier-Villars. 1892. 12mo. 3 francs.

Alheilig, M. *Recette, Conservation et Travail des Bois*. Paris: Gauthier-Villars. 1892. 12mo. 3 francs.

Duhem, P. *Lecons sur l'Électricité et le Magnetisme. Tome 3. Les Courants Linéaires*. Paris: Gauthiers-Villars. 1892. 8vo. 15 francs.

TABULATED RESULTS OF THE LAUFFEN-FRANKFORT TRANSMISSION.

We quote from the issue of June 17, 1892, of the (London) *Electrician*, the tabulated results of the famous Lauffen-Frankfort transmission of some 300 horse-power by means of high potential currents through a distance of about 109 miles.

The difference of potential on the line varied from 25,000 to 30,000 volts. The plant, which is only to be regarded as an experimental one, and notwithstanding the difficulties to be overcome, was able to show, as the result of some seventeen runs, an average efficiency between turbines and consuming apparatus of 73·3 per cent. Such figures show the wonderful efficiency of the electrical transmission of power as compared with any other method.

Table I, gives the results for the Lauffen-Frankfort transmission. Table II gives the results of a shorter transmission circuit of only one and one-fourth miles. The average total efficiency of eight runs in the latter case was 83·1 per cent.

The measurements in the first case were made by Profs. Dietrich, Stenger, Teichmann, Voit and Weber, Drs. Heins and Kopp, and Messrs. Nizzola and Schmoller. Those in the second case were made by Prof. Brauer, Dr. Wirtz, and Messrs. Friesse, Stapelfeldt and César. E. J. H.

TABLE I.—LAUFFEN TO FRANKFORT.

Time.	Horse-power Supplied by Turbine.*	Output of Dynamo.	Efficiency of Dynamo.	Output of Primary Trans-former.	Efficiency of Primary Trans-former.	Loss in Conductor.	Energy Supplied to Secondary Trans-former.	Energy Delivered by Secondary Trans-former.	Efficiency of Secondary Trans-former.	Efficiency between Dynamo and Consuming Apparatus.	Efficiency between Turbines and Consuming Apparatus.	Weather.
	horse-power	*horse-power*		*horse-power*		*horse-power*	*horse-power*	*horse-power*		*per cent.*	*per cent.*	
Oct. 11th — 1.30 to 1.40 . .	120·9	108·1	0·894	102·4	0·947	7·3	95·1	89·5	0·941	82·6	74·0	Bright,
1.50 to 2. 0 . .	121·1	108·3	0·894	102·6	0·947	7·6	95·0	89·4	0·941	82·4	73·8	Dry.
Oct. 12th.— 1.35 to 1.45 . .	127·0	114·4	0·900	108·7	0·950	8·0	100·7	95·1	0·944	83·0	74·9	Cloudy,
1.50 to 2. 0 . .	127·5	114·8	0·900	109·0	0·950	8·1	100·9	95·3	0·944	82·9	74·8	Rain at
2.10 to 2.20 . .	99·3	86·8	0.874	81·5	0·939	5·0	76·5	71·4	0·933	82·4	71·9	Times.
Oct. 13th.— 9.50 to 10. 0 . .	105·9	93·3	0·881	87·7	0·940	6·0	81·7	76·3	0·934	81·6	72·1	Rain till
10. 5 to 10.15 . .	105·9	93·3	0·881	87·7	0·940	5·9	81·8	76·4	0·934	81·7	72·2	Noon.
Oct. 14th —10.45 to 10.55 . .	151·8	139·1	0·916	132·8	0·955	12·8	120·0	114·0	0·950	81·8	75·1	
11. 0 to 11.10 . .	151·7	139·0	0·916	132·7	0·991	12·5	120·2	114·2	0·950	82·0	75·3	
11·35 to 11.45 . .	194·7	182·2	0·935	175·1	0·961	24·4	150·7	144·2	0·957	79·1	74·1	
12.30 to 12.40 . .	197·4	184·8	0·935	177·6	0·961	25·2	152·4	145·8	0·957	78·8	73·9	Dry.
1.30 to 1.40 . .	117·6	104·9	0·892	99·2	0·946	7·5	91·7	86·2	0·940	82·0	73·3	
1.45 to 1.55 . .	113·7	100·1	0·888	94·5	0·944	6·9	87·5	82·2	0·938	81·9	72·9	
2.30 to 2.40 . .	78·2	66·1	0·845	61·1	0.925	3·1	58·0	53·5	0·922	80·9	68·5	
Oct. 15th.—10.53 to 11. 3 . .	190·7	177·9	0·933	170·8	0·960	25·5	145·3	138·9	0·956	77·8	72·8	Rain in
11. 5 to 11.15 . .	190·0	177·3	0·933	170·2	0·960	24·9	145·3	138·9	0·956	78·1	73·1	Early
11.20 to 11.30 . .	189·7	177·0	0·933	169·9	0·960	24·6	145·3	138·9	0·956	78·1	73·2	Morning.

* The energy taken by exciter is included.

TABLE II.—PALMENGARTEN TO FRANKFORT EXHIBITION.

Primary Station. Dynamo by Deutsche Elektricitatswerke Aachen.				Secondary Machine. Motor by Deutsche Elektricitatswerke Aachen.							
Volts at Terminals.	Current in Ampères.	Total Output, Watts.	Revolutions per Minute.	Volts at Terminals.	Current in Ampères.	Energy Absorbed by Motor.	Revolutions per Minute.	Load on Brake Lever, Kgs.	Load Horse-power.	Efficiency of Motor.	Total Efficiency.
1,107	13·95	15,442	511	1,045	13·95	14,578	379	15	17·44	88·10	83·10
1,124	13·90	15,624	519	1,043	13·90	14,464	375	15	17·68	89·70	83 30
977	10·55	10,307	528	932	10·55	9,832	358	5	11·87	88·80	84 70
992	10·75	10,664	526	927	10·75	9,925	361	5	11·98	88·30	82·70
1,001	10·90	10,911	527	934	10·90	10,181	364	5	12·07	87·30	81·40
970	9·70	9,408	539	899	9·70	8,720	402	0	10·52	88·70	82·10
946	9·65	9,129	538	884	9·65	8,531	392	0	10·24	88·40	82·60
941	9·65	9,081	536	896	9·65	8,646	400	0	10·46	89·10	84·20
194	1·50	291	560	175	1·50	26,250	431	running light.	—	—	—